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LA GRANGE, ILLINOIS

OCTOBER 1959
VOL. 2 • NO. 10

- Cohen & Steinmetz — Amplitude and Phase Sensing Monopulse System Parameters, Part 1
- Hedrich — A New Receiver for Antenna Pattern Ranges
- Smith & Zawada — A 3-Megawatt, 15-Kilowatt S-Band Amplitron

the microwave journal

Robert H. Maier, Prin. Engr.,
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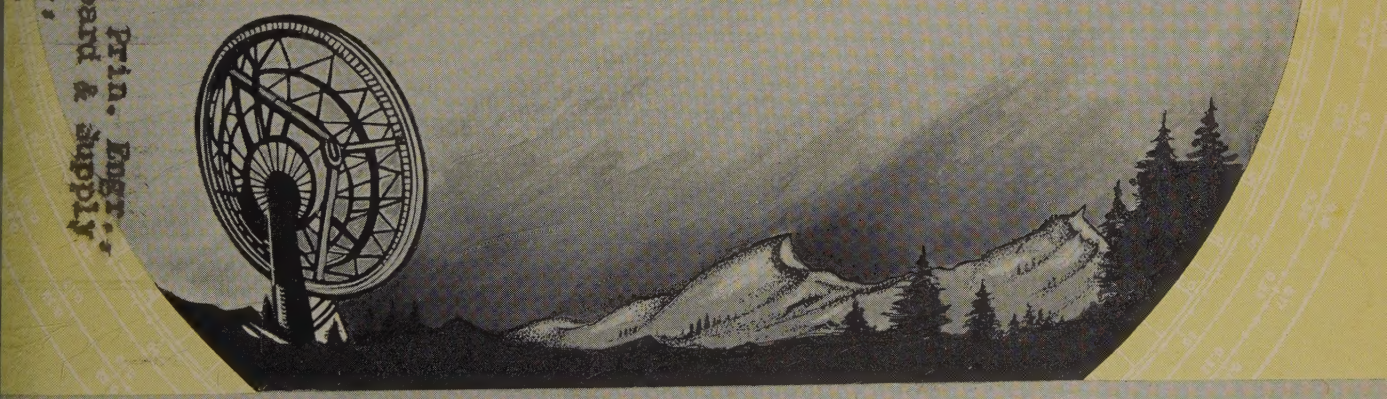

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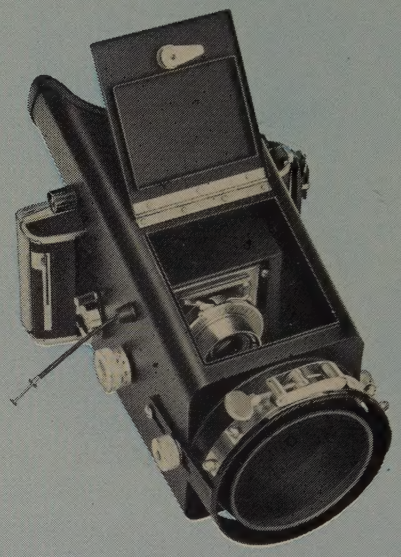

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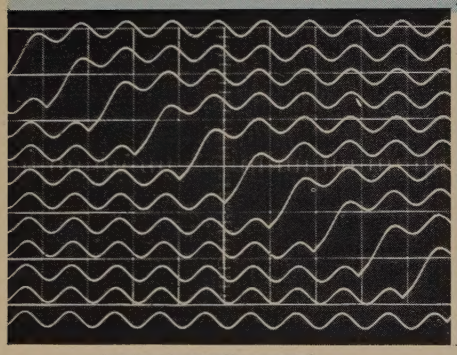

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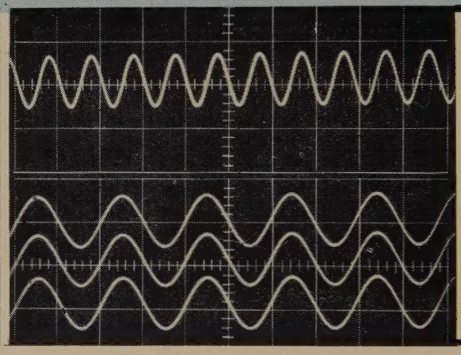
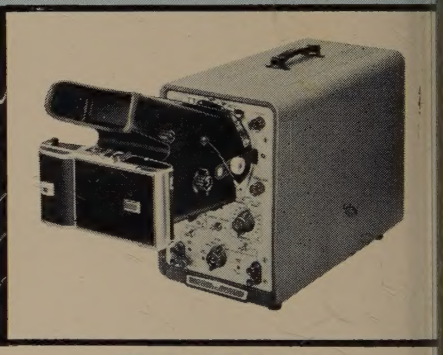


Two 4 x 10 cm field exposures. No overlapping



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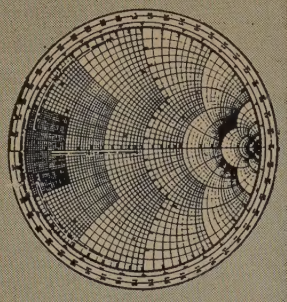

the microwave journal

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OUR COVER

Weinschel Engineering's Model BA-7 Antenna Pattern Analyzer is the heart of a video detector system designed primarily for r.f. crystals and useful for antenna pattern and field strength measurements. See page 28.

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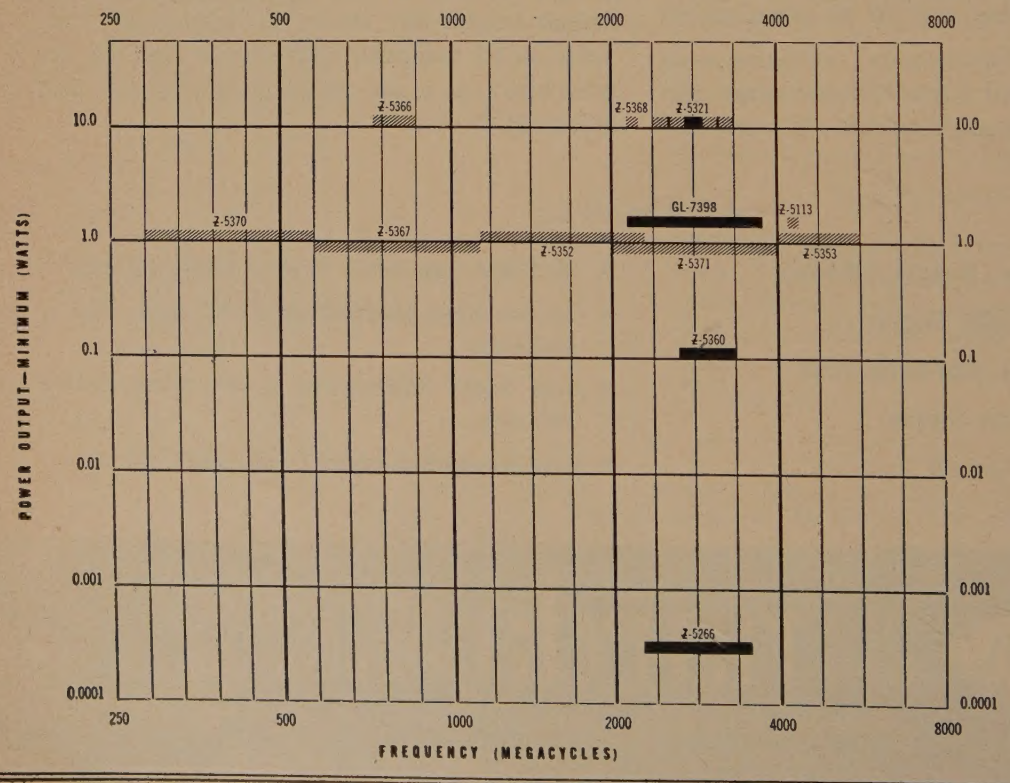
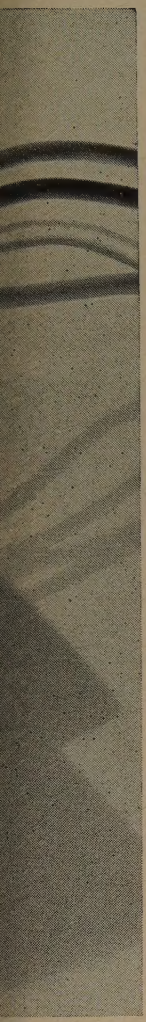
Voltage-tunable magnetrons now available are indicated by solid areas. Other developments are shown by cross-hatched areas.
▼

voltage-tunable magnetron spectrum chart



VOLTAGE-TUNABLE MAGNETRON IN FOR IMMEDIATE DELIVERY!



The General Electric GL-7398 voltage-tunable magnetron, a complete RF power source ideal for FM modulation, is now in volume production and available for immediate delivery. Moreover, samples are currently available or can be developed by use of proved technology to meet any need within the frequencies charted on the opposite page. The GL-7398 is designed for use in many applications, such as:

- FM telemetering or video transmission
- Beacon transmitters
- Local oscillators in electronically tunable radars
- Drivers in pulse-to-pulse frequency-shift radars
- FM altimeters
- Broad-band signal generators
- Countermeasure transmitters
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Output frequency can be varied linearly over a range of nearly 2 to 1 by sweeping the anode voltage. Power output is relatively flat at a minimum of 2 watts. The GL-7398 is a rugged, compact, packaged unit with these characteristics:

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FM rate	— 10 mcs or higher
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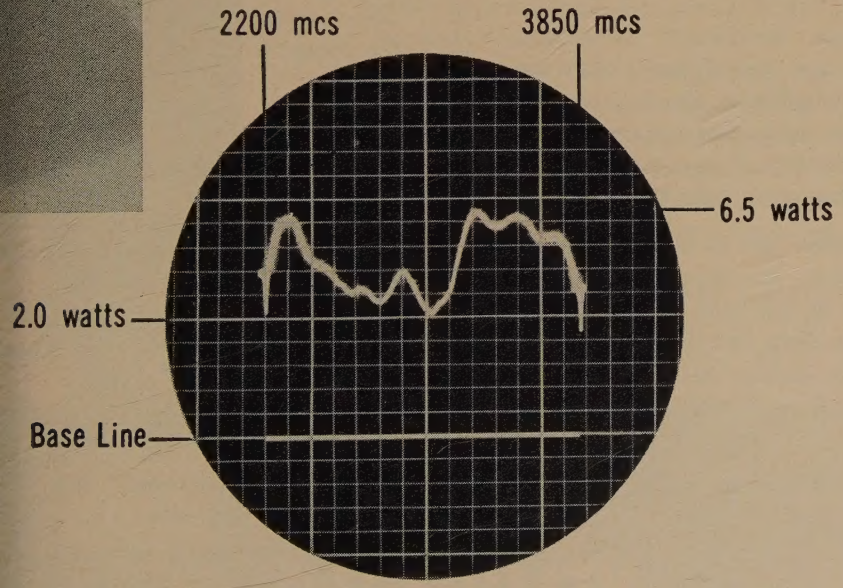
By use of internal narrow-band circuits, a variation (Z-5321) is available which gives a minimum of 10 watts power over a 200 mc bandwidth at a factory-predetermined centerpoint in the 2 to 4 kmc band. Other variations with built-in attenuators for local oscillator applications can be supplied (Z-5360 and Z-5266). *Power Tube Department, General Electric Company, Schenectady, New York.*



◀ Typical power—frequency of the GL-7398 shows power constant over the full band to within plus-or-minus 3 db.

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FROM THE EDITOR

We have noted with interest the reception given the journal in foreign countries. At the present time the magazine is mailed to about 1000 people in 43 different countries.

This should not be too surprising since many technical magazines have wide international audiences. However, it does help to underline the fact of an ever shrinking world.

Even though we are aware of the foreign efforts in the field of microwaves, we sometimes tend to become complacent about our own contributions. Fortunately, this attitude is not common to everyone in the industry. International societies and technical meetings have been on the increase since the end of World War II. More and more foreign microwave products are finding their way into our markets. Products which more than hold their own, both in terms of price and technical performance.

Few countries outside the United States have such a concentration of effort, government sponsored or otherwise. On the other hand what countries like England, France, Japan, West Germany and others lack in sheer numbers, they seem to make up in quality of performance. Some people tend to forget that had it not been for the rapid development of the magnetron in England the history of World War II might have been drastically modified.

This past summer we had occasion to pay a visit to the Russian Exhibit at the Coliseum in New York. We were especially interested in the display of microwave equipment.

There were slotted lines, adaptors, wavemeters, attenuators, noise sources, etc., in both waveguide and coaxial lines. They also had what appeared to be receivers, amplifiers, signal generators, spectrum analyzers and the like. The equipment appeared to be well designed with emphasis on the functional aspects. We regret that we did not have more time to devote to their equipment.

The moral of this editorial is simple. We as a microwave industry in the United States are not alone. We have competition in all parts of the world. The question is, will this hurt us or not. The answer — obviously no. The one thing that has helped stimulate progress in our industry in this country has been competition between companies. Expanding it to foreign countries can only help improve the end product.

The world is getting smaller. We itch in America, Europe scratches, and Asia heaves a sigh of relief.

Theodore S. Saad

LETTERS

Technical Editor
The Microwave Journal
Dear Mr. Saad;

The problem of the editorial of June 1959 Microwave Journal, wher concerns utilize advertising of propo equipment for market surveys, is of terest. Your comment on the suggest by a "man of stature" in the industry dicates you feel you might drive off vertising by following such a proposal

I see no reason why action such as suggested in the editorial could not applied as long as it is announced su ciently in advance and a date for acc plishment is adhered to carefully.

It should enhance the value of the to the advertiser since it could be bet relied upon by the user. It would produ a more professional magazine. Ra might be increased to offset the inco from purged "products."

I think it is simple if you determ "we will do it" rather than what are the possible vague pitfalls and objectio

Sincerely yours,

J. W. Miller PE(DC), (PGMTT, PGME, PG PGMIL, IR

(*Continued on page 13*)

• • •

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When requesting a change of a dress, please furnish the latest a dress at which you received *the mic wave journal.* Allow one month the change to become effective.

• • •

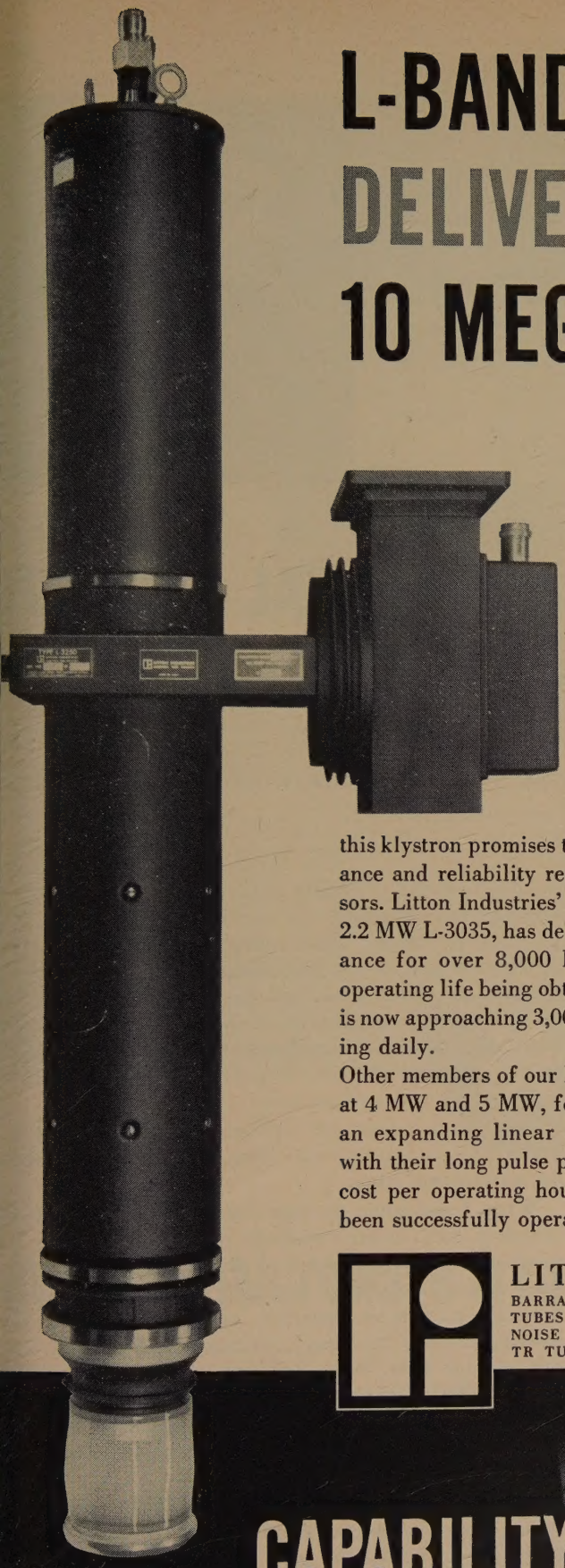
PAPERS

We wish to emphasize again th "the journal" is interested in rece ing papers from the industry.

Papers can be addressed to: "the microwave journal," 159 Lind Street, Wellesley 81, Mass.

In the West Coast area, plea address all papers to: "the microwave journal," Box 11 Palo Alto, California.

Papers submitted for publicati should include: 1. Two legible co ies. 2. An abstract. 3. ORIGINA of all the figures, with captio where needed. Photographs used figures should be glossy prints. A biographical sketch of the auth 5. A glossy photograph of the auth at minimum, 4" x 5", preferab 5" x 7" or 8" x 10".



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The long life obtained in these tubes provides low cost per operating hour which, combined with low initial cost, places linear accelerators within reach of many new users.

New developments now approaching production include tubes with higher power output, wide bandwidth, longer pulse length, modulating electrodes, and other features which will provide major improvements in systems where electronic tuning and shaped pulses are important.

The performance of our L-band klystron family has made Litton Industries the leading supplier of high powered klystrons in this range. Soon comparable families at other frequencies will enhance the reputation gained at L-band.

For your present needs, whatever your requirements for high power, be they radar, linear acceleration, or others, Litton Industries is *the* supplier. For your future needs, it's best to get our thinking early in your planning. Write to Litton Industries, Electron Tube Division, Office M7, 960 Industrial Road, San Carlos, California.

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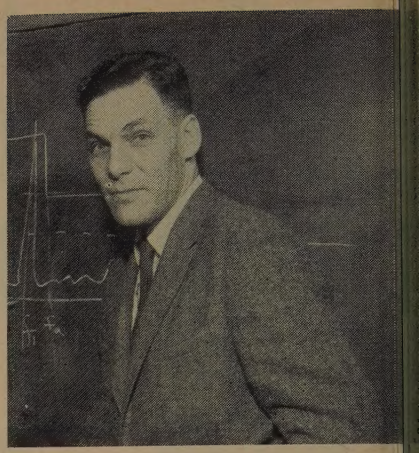
GUEST EDITORIAL



Mr. Frank Gardiner was educated at Harrow and the Imperial College of Science in England, transferring and graduating from M.I.T., in 1943 with a B.S. Aero and Thermodynamics. He then worked as Supercharger Design Engineer in the Aircraft Engine Development at Chrysler. He joined the Navy in 1944 and was with the Pacific Fleet until VJ Day. The next two years he was Jet Engine Advanced Development Officer with BuAer. He joined I-T-E in 1947 and was Chief Engineer of the Special Products Division until 1956. Since that time he has been Manager of the Engineering Products Section of this Division.

MICROWAVES AND THE MECHANICAL ENGINEE

Frank Gardiner

MANAGER, ENGINEERING PRODUCTS SECTION
SPECIAL PRODUCTS DIVISION, I-T-E CIRCUIT BREAKER CO.

Every industry is associated primarily with one field of endeavor and almost always crosses deeply into others. We associate the soap industry first with the advertising expert, and to some small degree the chemical engineer. An electric utility looks to me mostly as a financier's home but I believe also needs the electrical engineer. The microwave and antenna field is strictly the scientist's and engineer's ballpark where the electrical engineer is the pitcher, and, alas, so often the mechanical engineer the catcher, with physicists and managers giving good advice from the dugout.

I would like to discuss the role of the mechanical engineer in this game and point out some oddities.

We all know that sooner or later every concept in our field ends up on a drafting board via a mechanical engineer. Some of the most important attributes of a product are entirely within his control. In an antenna the radiation patterns, SWR and power handling capabilities are vital. Ability of the antenna to function in its environment and give long and trouble-free service, be mobile, light and low cost — all these critical matters are entirely in the hands of the mechanical engineer. One more point of concern is reliability. I venture to say that in the microwave field, and even more so, in the antenna field, reliability is exclusively a mechanical consideration, either of design or materials. The electrical engineer can contribute mainly by compromising his desires with the reliability requirements of the mechanical engineer. We have all read extensive and complex studies on reliability, but, however hard we try, this research cannot be applied to the antenna; it is founded on electronic component thinking. We can either conclude that antennas have no reliability problem or that no effort has yet been applied in this direction. Yet here is the paradox — the mecha ical engineer is usually the underdog! How many co panies have elevated their mechanical engineers to rea senior positions where fundamental decision making done. How often do we see electrical engineers maki decisions of key importance to mechanical considerati It is a fact in our industry that an area of vital consequen to the customer and user is grossly underrated both the industry and its customer.

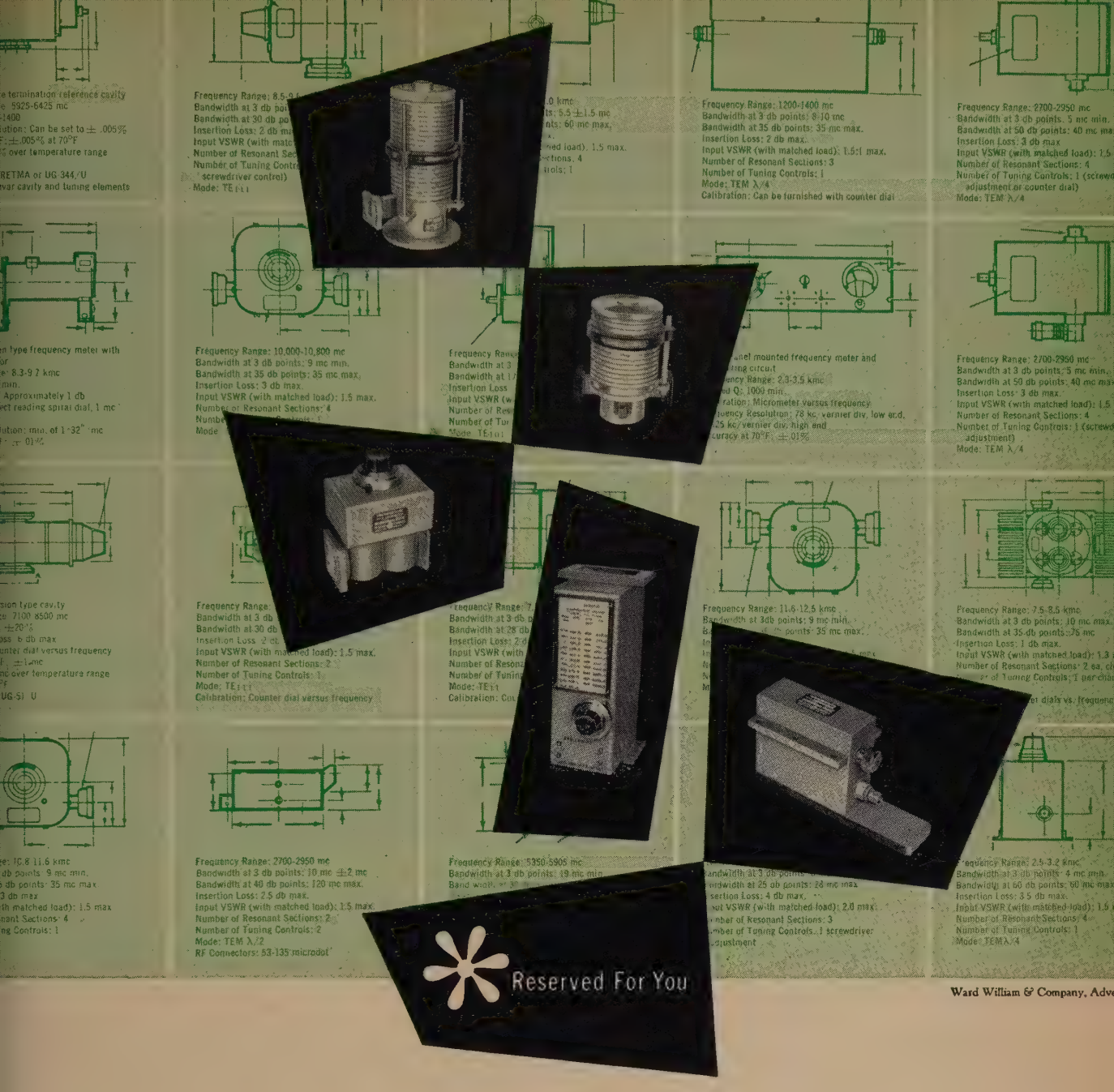
There is a reason for everything. I will suggest rather curious one later on. First, I want to pound hor my point some more.

When I was going through college, a pretty decent or complete with modern outlook, there were quite a fe mechanical engineers and I recall that none of us had keen desire, or light in our eyes, toward the electron industry, microwave, antennas or otherwise. We we heading towards machinery, aircraft, transportation, aut motive and such fields, and our professors were rig with us. Today, it seems to me, the position has chang not at all, there are fewer mechanical engineers and mo electrical; but just as few mechanicals heading for the business as such.

Yet, I am very glad that through accident and circu stance, I have landed in the r-f industry. There is so mu to be done, so little has been done and there are so fe of us. What more challenge and thrill can one ask for?

Naturally all those working in a field which is bo mechanical and electrical must understand the langua the terms, the problems on both sides of the fence. No o is surprised to find electrical engineers theorizing mechanical design problems, but it seems to be the

(*Continued on page 10*)



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Microwaves and the Mechanical Engineer

(*Continued from page 8*)

cepted standard that a mechanical engineer, however good, cannot possibly understand the mysteries of r-f engineering or physics or the underlying mathematics. Again, there is some truth in this, but it is neither good, nor desirable, nor necessary, nor sufficient. I certainly think that, from the industry's point of view and more especially the customer's best interest, this shall not and must not be.

In my opinion the key reason for this state of affairs is this: the world of mechanical engineering is too tough, just that! Consider how much progress the electrical engineer and physicist can make with mathematics, especially when a nice digital computor is thrown in. The mechanical engineer is not so lucky; many basic phenomena are very poorly understood and not capable of mathematical expression at present. The most basic and fundamental facts of material failure in strength, in fatigue and in wear, are so little understood. Stress analysis is limited to elasticity yet heaven help us if we would ever have to deal with truly elastic materials in antennas (such as glass). Almost always even the most simple devices such as gears and trusses are analyzed either by greatly oversimplified assumptions or by purely empirical results. But there is no doubt in my mind that the tremendous progress of the electrical, and more particularly, the electronic art is largely attributable to the ability of mathematics to explore, predict, and direct far in advance of bench tests and physical research. I am reluctant to admit that the mechanical contributions made in the last ten years in the antenna field are not impressive. The drive mechanism of a 1950 antenna system or the reflector structure are little different from those now on the drafting boards. There are again reasons: first, it is very difficult and tedious to make progress in this area; and second, because little or no development effort has been applied. Yet, savings in weight and cost and improvement in reliability are certainly obtainable for the asking.

The type of designing and testing which, under the present rules, must be followed, is not suitable to mechanical problems at the present state of the art. Almost invariably the true reliability of an antenna is not apparent from the formalized testing that is done. When later the bugs appear, the test procedures and test methods should be rewritten.

What should be done to improve this situation? Although I by no means have an answer, I would submit a few suggestions:

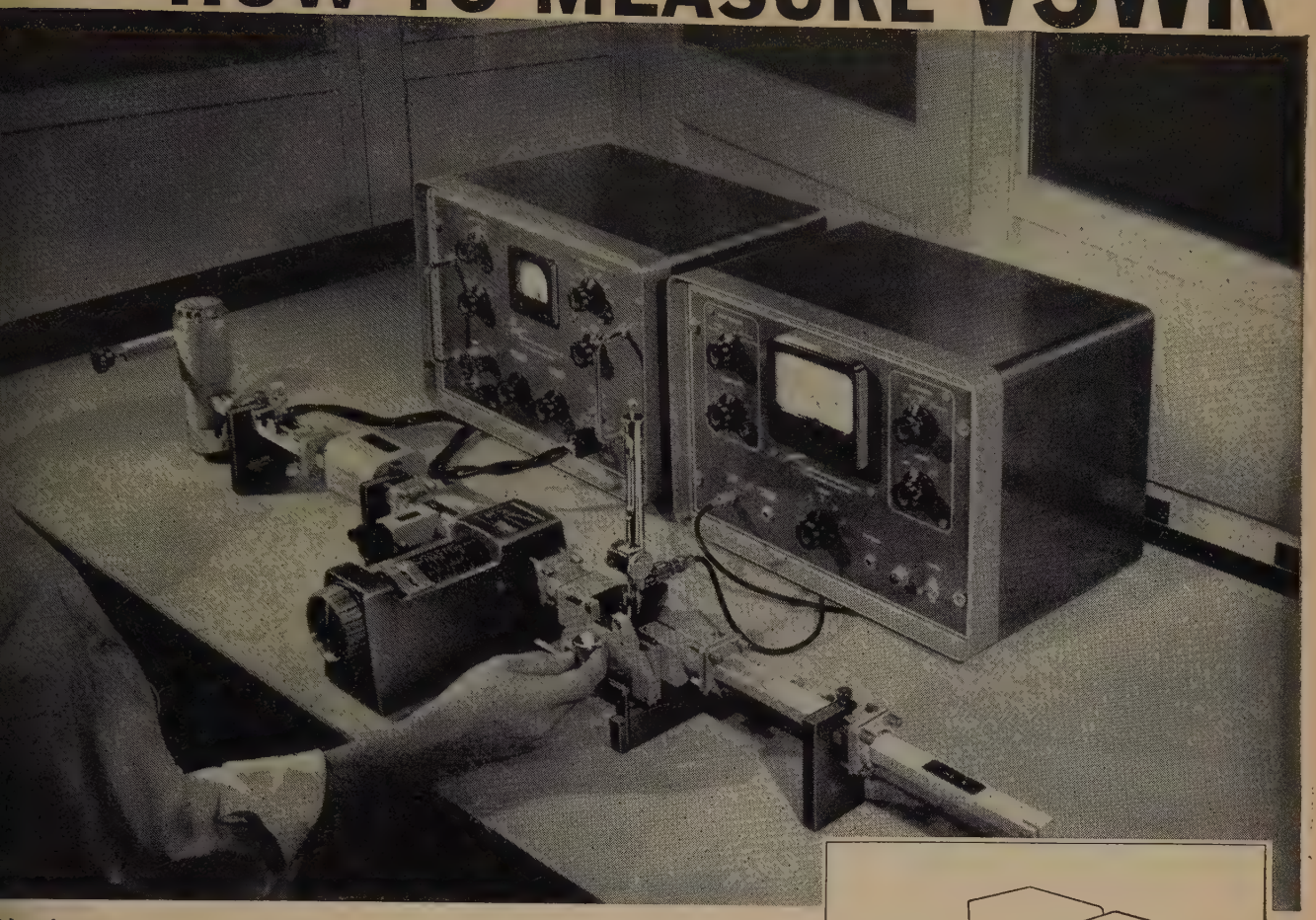
a. The general specifications for electronic equipment — MIL-E-16400 (USN) and MIL-E-4158 (AF) and MIL-P-11268 (SC) are not suitable for antennas and microwave components. They are no doubt fine for electronic parts assemblies such as receivers, data handling and display equipment. They do not represent the best interest of the services for our business. I would suggest that a committee of microwave and antenna industry representatives and government personnel attempt to draft general specifications for antennas and microwave components for each service.

b. The philosophy of "designing" a new antenna or pedestal for each radar be reviewed. In many cases existing pedestal designs which have been in service for a long time can be revised to develop them to a higher state of reliability, lower weight or cost. In view of our present ability to calculate, test and predict designs to optimum success we must "develop" designs and feel our way. This does not always work for basic reasons but there are many cases where it should be done. It is certainly common practice in the machinery, aircraft engineering and automotive industry. Who would dream of "designing" a new diesel engine and putting it into production after a few formal dynamometer tests. The reason we have gotten away is because we continuously overdesign but still reliability is not good enough. The result has been excessive weight, cost and maintenance — the using services have just got used to this.

c. We must attract the best mechanical engineers to our industry. We certainly have the problems and the challenge, we must encourage these engineers by devoting more time and effort to mechanical improvement. Programs to improve our knowledge of fundamentals must be initiated. I wonder what share of R & D money has been devoted to mechanical improvement? Am I high at 1%? Yet, antennas are a very large part of the weight and cost of any system and a small R & D expenditure could easily achieve large production cost savings. Some of the fundamentals that need attack are wind torque on antennas, wind load and its proper assessment for mechanical design, the mechanical properties of dielectrics, lubrication requirements in service, motor design for the highly varying torques of antennas, corrosion effects and protection, etc. If we will emphasize these important features and seriously pursue them, the best mechanical engineers will be attracted in due course.

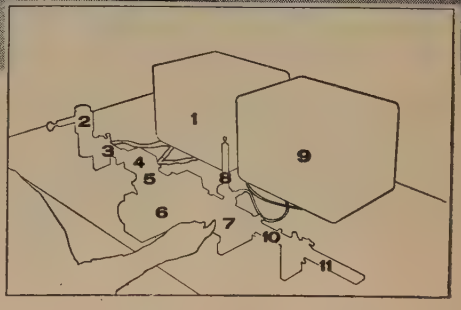
d. If and when the mechanical art is to be advanced and better results are desired, then the antenna industry must be in closer touch with the using service and fewer and more specialized groups must concentrate on these equipments. The day where every electronics company has a small antenna group, who turn out one design a year, is passing and a specialized division, or group, serving many systems must broadly apply their knowledge and highly developed art. The idea of a general engineering group capable of designing cabinet chassis and consoles one day and antennas the next is characteristic of a young art in incomplete development stage. The more refined state of specialization is characteristic of high development and optimum products — this cannot be achieved by a few part-time engineers, however good.

HOW TO MEASURE VSWR



his microwave measurement bench is for the determination of Voltage Standing Vave Ratio using the slotted-line technique. Other systems utilizing directional ouplers or magic tees for measurement of VSWR are known, but the use of the lotted Section assures maximum accuracy.

Regardless of the technique used, accurate readings depend on the precision of ie test instruments involved. When it comes to microwave test instruments PRD roduces the widest range of the most precise equipment available anywhere in ie world.



You will notice in the measurement bench shown that there are four test components separating the klystron tube mount from the Slotted Section. These are: Slide Screw Tuner, ferrite Isolator, Level Set Attenuator, and a broadband direct eading Frequency Meter. THE USE OF THESE FOUR COMPONENTS IN THE EST LINE IS MANDATORY FOR PRECISE VSWR MEASUREMENTS!

The reason for this is clear when you consider the interrelationship between SWR, power, and frequency.

The Slide Screw Tuner is used to match the klystron output to that of the tandem st line, thereby maximizing its output and increasing its stability.

The use of the ferrite Isolator assures klystron frequency and power stability by ielding the source generator from changes in impedance further down the line. accomplishes this with negligible attenuation of the incident power. The Level et Attenuator is used to adjust the amount of power feeding the remainder of the st line.

The reaction Frequency Meter accurately monitors the output of the klystron a resonant dip on the Standing Wave Amplifier.

A Slotted Section, tuned Broadband Probe, Standing Wave Amplifier, and matched ermination complete the precision waveguide, X-band, VSWR bench. A Klystron ower Supply to provide the signal source with power and modulation and a Fixed aveguide Attenuator to simulate the unknown are also shown.

Special problems in VSWR and other related measurements? — Contact our pplications Engineering Department.

We at PRD have pioneered the development of precision microwave test instruents . . . PRD is the only pioneer company today producing microwave test struments exclusively. In fact, we're just about the largest microwave company the world . . . our cable address is MICROWAVE, New York, USA.

For technical details and specifications covering products shown write:

TEST INSTRUMENTS USED IN THIS X-BAND VSWR BENCH

1—809 Klystron Power Supply, catalog page F-10
2—703 Shielded Tube Mount, catalog page F-8
3—303-A Slide Screw Tuner, catalog page B-14
4—1203 Isolator, catalog page A-21
5—159-A Level Set Attenuator, catalog page A-17
6—535 Frequency Meter, catalog page D-12
7—203-D Slotted Section, catalog page B-11
8—250-A Broadband Probe, catalog page B-12
9—277-A Standing Wave Amplifier, catalog page E-7
10—UNKNOWN—represented by a 140 Fixed Waveguide Attenuator, catalog page A-11
11—116-A Waveguide Termination, catalog page A-19

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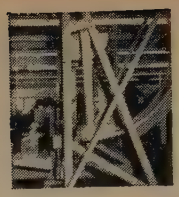
202 Tillary Street, Brooklyn 1, New York. Telephone: ULster 2-6800

West Coast Office: 2639 So. La Cienega Blvd., Los Angeles 34, California, Telephone: UPton 0-1940



Hammer drop typifies tough environmental test that assures dependability of Sperry TWT amplifiers.

Tubes are built for rugged service—at **SPERRY**

New high-power S-Band Traveling Wave Amplifier

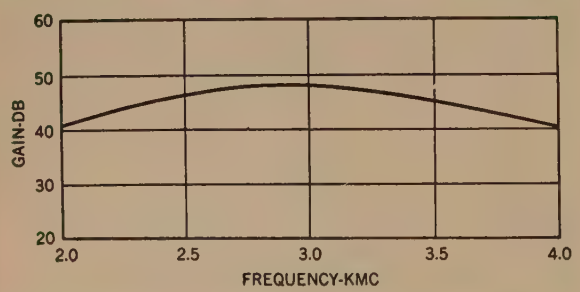
2.0-4.0 kmc with 300 watts nominal output power

STS-101

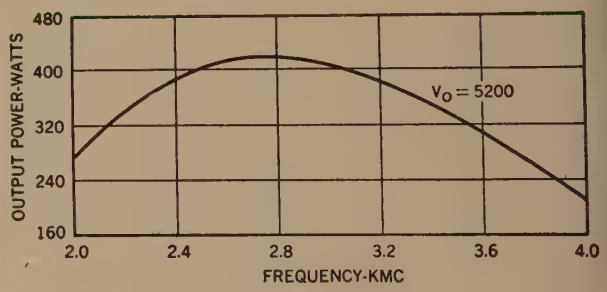
SPECIFICATIONS

Frequency Range	2.0-4.0 kmc
Small-Signal Gain	40 db
Output Power	300w (nom)
Saturated Gain	35 db
Beam Voltage	5.2-5.6 kv
Beam Current	380 ma
Heater Voltage	6.3 v
Heater Current	2.6 a
Helix Current (full)	8 ma

Small-Signal Gain vs Frequency



Saturated Power vs Frequency



This new broadband, high gain cw traveling wave amplifier is the only tube in S-band—delivering 300 watts nominal—for service in microwave systems, high performance tracking radars, high frequency communications networks and other applications where high power and high gain in the 2.0 to 4.0 kmc frequency range are desirable. This tube features rugged, all metal-ceramic construction for high performance aircraft environments and is short-circuit stable.

The STS-101 may well be suited to projects or problems you are working with now. Write for data regarding your application.

SPERRY

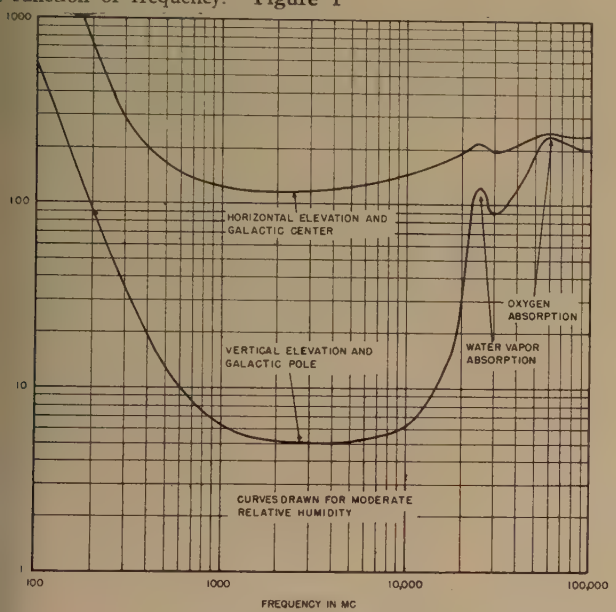
ELECTRONIC TUBE DIVISION, *SPERRY GYROSCOPE COMPANY, GREAT NECK, NEW YORK, DIVISION OF SPERRY RAND CORPORAT*
Address all inquiries *to Great Neck or Sperry offices in Brooklyn, Boston, Philadelphia, Los Angeles and Montreal. Export Dept., Great Neck, New*

(Continued from page 6)

etters
itor
microwave journal
ar Sir:

There has been much printed in the past few years concerning contribution of atmospheric and celestial noise to receiver sitivity. This is proper, since, with the advent of very low-se amplifiers, such as the maser and reactance (parametric) plifiers, these contributions may be the limiting factor in many plications. That these limitations be thoroughly understood l placed in proper perspective is extremely important, for other-se when striving for the ultimate in sensitivity, unwise speci-tions may be placed on equipment. Often, the statements in literature only tell a part of the story; such a case is Ewen's icle in the March 1959 issue of *the microwave journal.*

In a figure called the "Thermodynamic Microwave Cosmic indow," Ewen plots "antenna temperature" as a function of quency. The curve is correct as far as it goes, but without ther explanation, it can be quite misleading. "Antenna tem-rature" is a term used to describe the noise power available m the antenna terminals, and is a function of galactic noise, nospheric absorption, sidelobes and backlobes absorbed by the th and sky, and antenna losses. Ewen's curve applies *only* an *ideal* antenna (no sidelobes, backlobes, or resistive losses) inted at the *zenith.* As such, it is of very limited value unless ditional information is included. It should properly be called pace temperature (a term Ewen uses in his text) at zenith as function of frequency." Figure 1



A set of curves that gives a somewhat better view of reality given as figure 1 attached. Here we are still referring to an *al* antenna but we show the results for both vertical and hori-ital beam elevation. The vertical curve is Ewen's for minimum actic noise (galactic pole). It must be emphasized that these ves also take no account of the antenna lobe structure, and that higher antenna temperature for horizontal elevation is due to orption in the atmosphere (this loss has been computed to be an effective temperature of 260 degrees Kelvin) and to the use the galactic *center* temperature. Above 1000 Mc, the space perature is almost entirely due to atmospheric absorption. ure 2 is the set of curves from which the absorption contribu-ns were computed by multiplying the ordinate by 260° K.

t is impossible to draw a universal set of curves which are licable to all antenna systems. Each system must be analyzed h full knowledge of the *complete* antenna pattern, and changes this pattern as a function of pointing angle. Then, by an in-idual ray tracing procedure, the effective antenna temperature be determined. Simplifying assumptions are in order so that computation can be reduced to a reasonable one, but over plification can eliminate any meaning from the final result. study was made by AIL in connection with a Department of fense contract and a typical *antenna* temperature curve drawn function of elevation angle. This was reported in the Proc. , May 1958, page 4A.

NEW FROM NARDA

MICROWAVE MODULATOR

accepts over 40 magnetrons!

Here's the first of a series of new products from Narda's recently-established High Power Electronics Division! A high power Microwave Modulator that permits installation **inside the unit** of any of more than 40 magnetrons! Complete, compact and self-contained, it accepts magnetrons covering 3,200 mc to 35,000 mc, with peak outputs from 6 KW to 120 KW. Model 10001 features a completely interlocked circuit, with all high voltage leads and connections **internal,** for maximum safety; solid state high voltage bridge rectifiers for longer life and reduced heat output (prolonging life of other components, too); and built-in meters and viewing connectors for all principal parameters.

Other features are shown below. For complete specs and a list of at least 40 magnetrons suitable for use with the 10001, write Narda's High Power Electronics Division (HPED) at Dept. MJ-7.

SPECIFICATIONS

High voltage supply: Continuously variable from 0 to 4 KV at 100 ma; **Magnetron filament supply:** Cont. variable from 0 to 13 volts at 3 A; **Rep. rate generator range:** Cont. variable from 180 to 3000 pps; **Pulse width:** 1 microsecond at 70% points, rise time 0.15 microseconds, max. slope 5% (other pulse widths available); **Size:** 38" h, 22" w, 18" d. **Weight:** 150 lbs.

Complete 1959 catalog available on request.

the narda microwave corporation
HIGH POWER ELECTRONICS DIVISION
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WAVEGUIDE IN-LINE ROTARY JOINTS

DIC NO.	W.G. SIZE	FREQUENCY KMC/S	VSWR (Max)	INSERTION LOSS (Max)	"WOW" (Max)	POWER HANDLING Peak	Average
445*	3 × 1½	2.6–3.95	1.5 : 1	0.1 db	.05 db	370 KW	3 KW
545*	2 × 1	3.95–5.85	1.5 : 1	0.1 db	.05 db	160 KW	2 KW
645*	1½ × ¾	5.85–8.2	1.5 : 1	0.1 db	.05 db	73 KW	1 KW
845*	1 × ½	8.2–12.4	1.5 : 1	0.1 db	.05 db	37 KW	1 KW
945*	.702 × .391	12.4–18.0	1.5 : 1	0.1 db	.05 db	16 KW	1 KW
1045*	½ × ¼	18.0–26.5	1.5 : 1	0.1 db	.05 db	8 KW	½ KW
1145*	.360 × .220	26.5–40.0	1.5 : 1	0.1 db	.05 db	3 KW	½ KW

* Patents applied for.

SINGLE CHANNEL COAXIAL ROTARY JOINTS

DIC NO.	LINE SIZE	FREQUENCY MC/S	VSWR (Max)	INSERTION LOSS	"WOW" (Max)
2045	6⅛	100–140	1.15 : 1.0	Negligible	0.5 db
2046	6⅛ (75 ohm)	400–700	1.2 : 1.0	Negligible	.05 db
2047	3⅛	200–400	1.2 : 1.0	Negligible	.05 db
2048	3⅛	400–600	1.1 : 1.0	Negligible	.05 db
2049	⅞	400–450	1.1 : 1.0	Negligible	.05 db
2049-2	⅞ (46.5 ohm)	2170–2320	1.15 : 1.0	Negligible	.05 db
2049-3	Type N	200–300	1.5 : 1.0	Negligible	.05 db
2050	1⅝	2100–2400	1.15 : 1.0	Negligible	.05 db
2400-1	⅜	4–15 kmc /s	1.8 : 1.0	Negligible	.05 db

DUAL CHANNEL COAXIAL ROTARY JOINTS

DIC NO.	CHANNEL	LINE SIZE	FREQUENCY MC/S	VSWR (Max)	INSERTION LOSS	"WOW" (Max)
2246	Main Auxiliary	6⅛ 3⅛	380–440 380–440	1.15 : 1.0 1.2 : 1.0	Negligible Negligible	.05 db .05 db
2247	Main Auxiliary	6⅛ Type N	415–465 I.F.F.	1.15 : 1.0 1.2 : 1.0	Negligible Negligible	.05 db .05 db
2248	Main Auxiliary	3⅛ 3⅛	785–815 785–815	1.1 : 1.0 1.15 : 1.0	Negligible Negligible	.05 db .05 db
2249-1	Main Auxiliary	⅞ BNC	2170–2320 30	1.1 : 1.0 1.1 : 1.0	Negligible Negligible	.05 db .05 db
2249-2	Main Auxiliary	Type N BNC	2150–2350 30	1.15 : 1.0 1.1 : 1.0	Negligible Negligible	.05 db .05 db
2250	Main Auxiliary	⅞ ⅞	215–260 215–260	1.1 : 1.0 1.25 : 1.0	Negligible Negligible	.05 db .05 db

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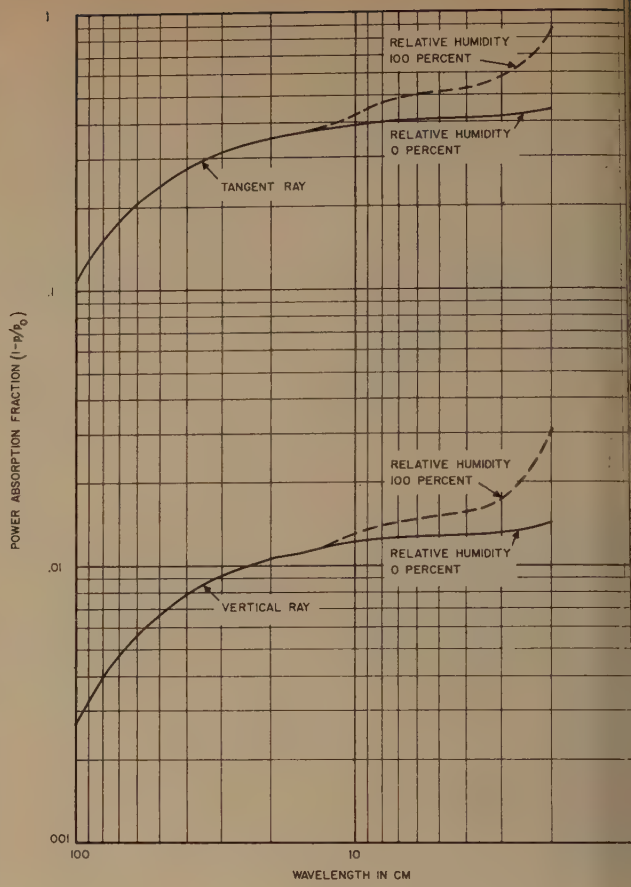


Figure 2

In conclusion, Figure 1 shows two curves between which t
space temperature contribution for antenna systems will lie.
obtain the correct antenna noise temperature, the space temperatu
must be modified by the contributions due to side lobes, backlob
antenna resistive losses and the fact that intense "radio stars" (
cluding the sun) may lie in the major or minor lobes of the a
tenna pattern. Furthermore, if the source of the signal is se
arated from the antenna by an attenuating path, this attenuati
must be taken into account in determining the available sign
power at the antenna terminals.

Very truly yours,
AIRBORNE INSTRUMENTS
LABORATORY
Division of Cutler-Hammer, I
J. C. GREENE
Section Head
MATTHEW T. LEBENBAUM
Department Head
Applied Electronics Departme

• • •

Editor
microwave journal
Dear Sir:

I have received several comments concerning Figure 2 in
article: *A Thermodynamic Analysis of Maser Systems,* which
peared in the March issue of the Journal.

In the figure the co-ordinates were identified as: "Ante
temperature °K" vs. "Frequency in Mc/s."

As indicated in the text, this is not a plot of antenna temp
ture vs. frequency, but rather, space temperature vs. frequency,
in particular, should be identified with the following co-ordina
"Space temperature at Zenith" vs. "Frequency in Mc/s."

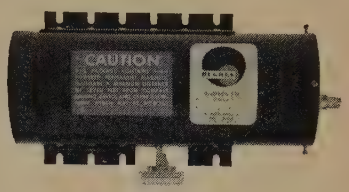
Space temperature was not the principle subject of the pa
However, I do feel it is of sufficient interest to merit a sepa
paper devoted exclusively to this subject.

Sincerely,
"Doc"
H. I. EWEN
Ewen Knight Corpora

Hughes microwave tubes

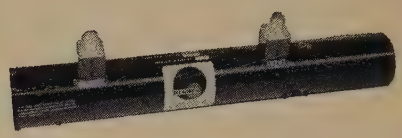
TOUGH ENOUGH FOR AIRBORNE RADAR

Rugged, compact, light in weight... all Hughes Microwave Tubes have withstood the most severe requirements of airborne radar systems and therefore can be applied in the most taxing of environmental problems.



KU BAND BACKWARD WAVE OSCILLATOR

The Hughes Type LOU-2 is a precision built oscillator which tunes over the frequency range of 12.4 to 18.0 kmc. Typical power output over band is 10 to 60 milliwatts. The tube is housed in a self-contained permanent magnetic focusing package so that a separate power supply for a focusing electromagnet is not required.



S-BAND TRAVELING WAVE AMPLIFIER

Periodically focused, the type MAS-1A has a peak power output of one kilowatt over a band of 2-4 kmc at duties up to 0.005. The tube has a gain of 30 to 33 db, giving an excess of one kilowatt over most of the band. When two tubes are operated in cascade, the one kilowatt output can be obtained with a drive on only one milliwatt.

S-BAND BACKWARD WAVE AMPLIFIER

The Hughes type PAS-2 is a narrow-band, voltage-tuned amplifier that is designed for use as an r-f preamplifier stage in contemporary radar communications and other microwave receivers. Features: frequency range 2.4-3.5 kmc, insertion noise figures on order of 4½ db, tube noise figures of less than 5 db, voltage-tuned, crystal protection, spurious input signal elimination, cold isolation greater than 80 db and image rejection.

For additional information please write: HUGHES PRODUCTS, *Electron Tube Division, International Airport Station, Los Angeles 45, California.*

For export information, write: HUGHES INTERNATIONAL, *Culver City, California.*

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Creative Microwave Technology

Published by MICROWAVE AND POWER TUBE DIVISION, RAYTHEON COMPANY, WALTHAM 54, MASS., Vol. 1, No. 7

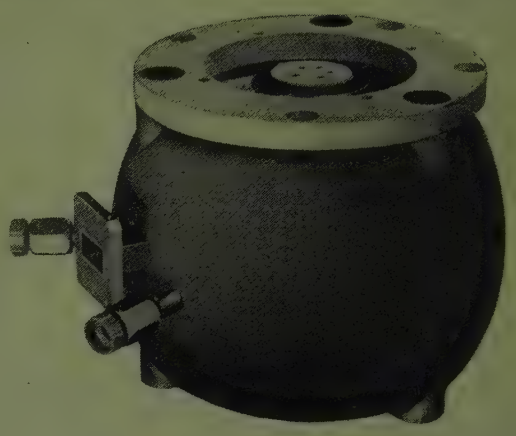
RAYTHEON X-BAND BACKWARD WAVE OSCILLATORS

-- for countermeasures and high-power chains

The QK-634, a voltage tunable, crossed-field, "M" type backward wave oscillator embodies the latest design and manufacturing techniques developed by Raytheon and offers many advantages over its predecessor, the French carcinotron.

Raytheon, the first company in the U.S. to recognize the merits of the "M" BWO, is presently producing large quantities of a variety of these highly efficient tubes.

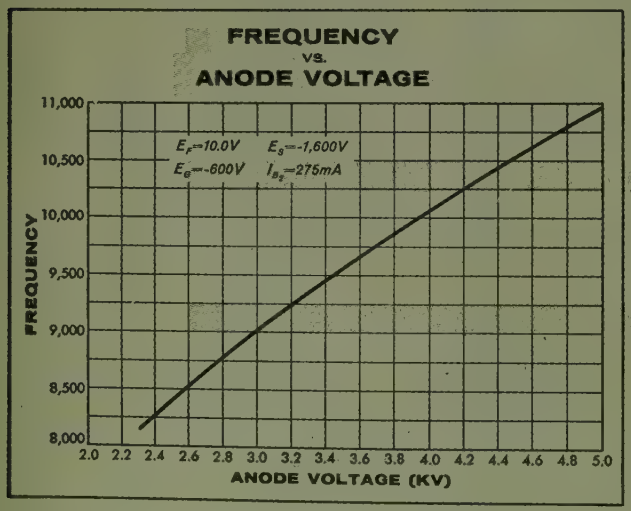
The liquid-cooled QK-634 features all ceramic and metal construction for reliable high-temperature operation, low-temperature coefficients, and a minimum of spurious response. Hobbing of the slow-wave structure, a Raytheon-developed technique, assures accurate construction of the frequency dispersive delay line necessary for consistently reproducible performance. Amplitude and/or frequency modulation can be accomplished more rapidly than with conventional mechanically-tuned tubes--up to and exceeding 10 Mc. Equipped with an integral magnet and a standard ½" by 1" RF waveguide output, the QK-634 weighs 20 pounds and can be mounted in any position.

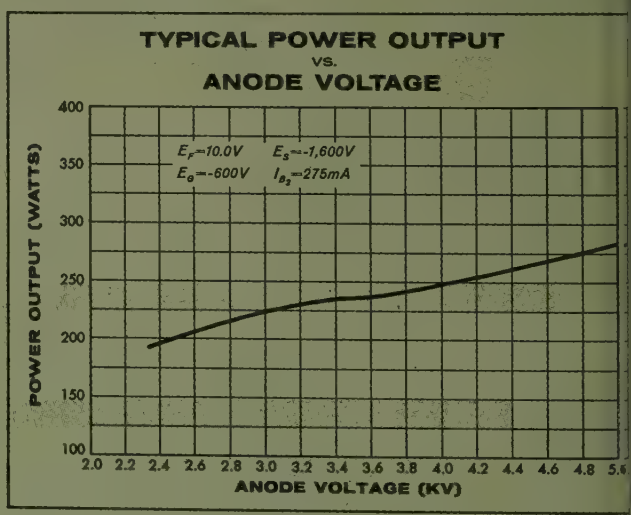


QK-634 Backward Wave Oscillator

Typical Operating Characteristics--QK-634

Frequency Range	8,150 to 11,000 Mc
Power Output	150 watts (min.)
	200 to 250 watts (nom.)
Output Flange	Mates with UG40A/U modified for clearance holes
Tuning Sensitivity	1.0 Mc/v





Other available 200 watt BWO's in this series include the QK-625 and QK-659, which cover the 2,500-4,450 Mc band.

Excellence in Electronics

RAYTHEON

You can obtain detailed application information and special development services by contacting: Microwave and Power Tube Division, Raytheon Company, Waltham 54, Massachusetts

A LEADER IN CREATIVE MICROWAVE TECHNOLOGY

CIRCLE READER SERVICE CARD 10

This man is using the industry's most advanced swept microwave oscillator

now available from

ALFRED ELECTRONICS

No other sweeping oscillators offer as many solid advantages as Alfred Electronics' new series 620 models, built by the industry's leading manufacturer of high quality, broadband microwave instruments. Note these features:

★ **Six models, covering 1 to 18 kmc.** Broadest frequency range available. Electronic sweep of RF output, or extremely stable CW operation.

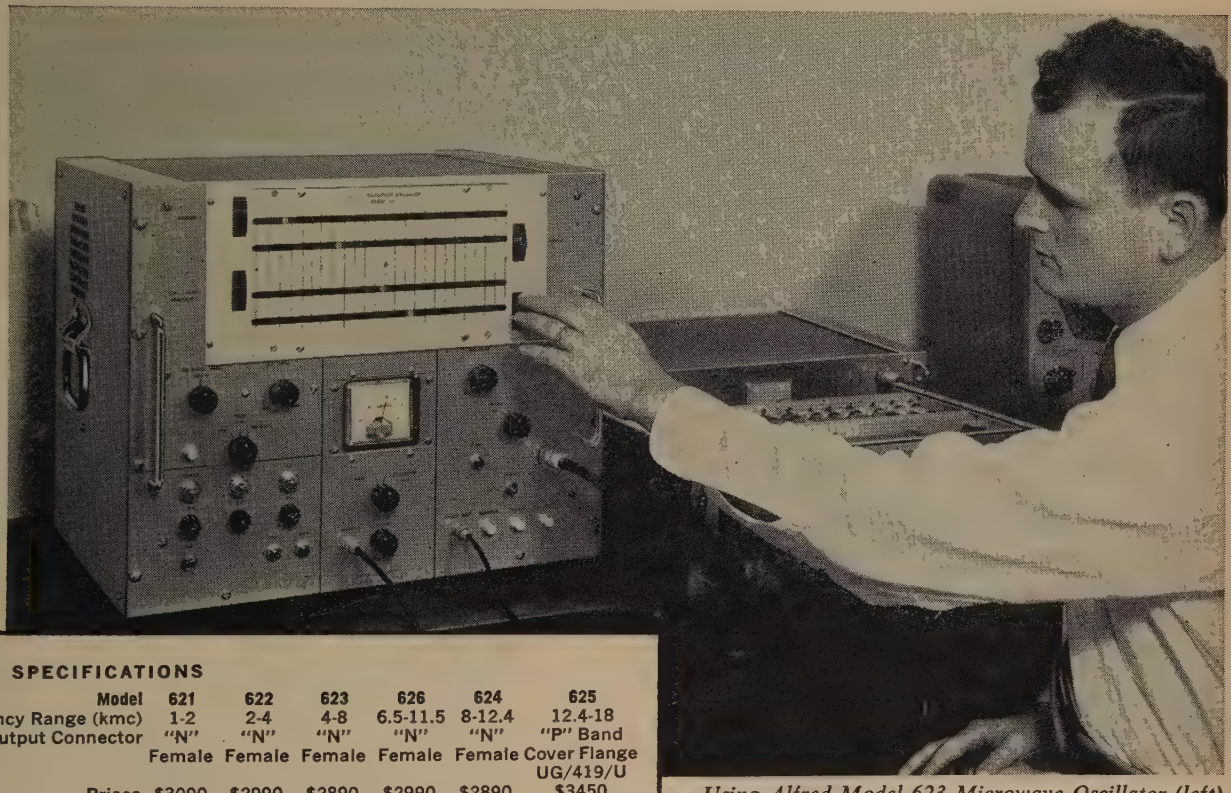
★ **Linear frequency sweep coverage** over all or part of each band for rapid evaluation of reflection coefficient, gain, attenuation and other network transfer characteristics.

★ **Two adjustable frequency markers** for convenient calibration of oscilloscopes or recorders. Markers save valuable test time by indicating either band limits or intermediate frequency values. An exclusive Alfred feature on all models.

★ **0.5 microseconds rise and fall** response to AM—equivalent to a 2 megacycle band pass. Another exclusive Alfred feature.

★ **Quick Look readout.** See frequency range, markers and sweep time at a glance. No cumbersome calculating.

★ **Fast sweep** for flicker-free oscilloscope presentation; slow sweep for mechanical recorder operation.



Using Alfred Model 623 Microwave Oscillator (left) to test small signal and saturation gain of Model 503 Traveling Wave Tube Amplifier. Microwave Leveler, Alfred Model 704, holds power output from oscillator constant within ±1 db.

BRIEF SPECIFICATIONS

Model	621	622	623	626	624	625
Frequency Range (kmc)	1-2	2-4	4-8	6.5-11.5	8-12.4	12.4-18
RF Output Connector	"N" Female	"N" Female	"N" Female	"N" Female	"N" Female	"P" Band Cover Flange UG/419/U
Prices	$3090	$2990	$2890	$2990	$2890	$3450

GENERAL

FREQUENCY CONTROL: Continuously adjustable with direct calibrated dial. Calibration accuracy, 1%.

POWER OUTPUT (minimum): 10 mw. Continuously adjustable from zero to maximum.

VSWR (maximum): 2:1.

SWEEP

SELECTOR: Recurrent sweep, single sweep, CW, and external on panel switch.

CONTROL: Single sweep, triggered by panel button, or external positive going signal 20 volts or greater.

SWEEP WIDTH: Continuously adjustable from 0 to any part of entire frequency range.

TIME: 100 to .01 seconds.

MONITOR OUTPUT: Positive linear sawtooth, 45 volts peak; Blanking out, 75 volts negative.

EXTERNAL SWEEP: 200 volts gives full sweep width.

AMPLITUDE MODULATION

INTERNAL SQUARE WAVE: RF output alternately 0 and unmodulated CW value. Frequency 800 to 1200 cps.

EXTERNAL: 30 volts maximum signal increases RF output from 0 to maximum.

POWER INPUT: 105 to 125 volts; 60 cps.

Write us for complete details of these new oscillators. We'll also send you our new short form catalog, which describes Alfred's complete line of packaged traveling wave tube amplifiers.

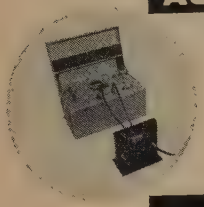
Address Dept. 6810.

ALFRED ELECTRONICS

897 COMMERCIAL STREET
PALO ALTO, CALIFORNIA

From the AMCI Catalogue

AUTOMATIC IMPEDANCE PLOTTERS



- *Continuous impedance display with frequency*
- *Available in portable and rack-mounted units*

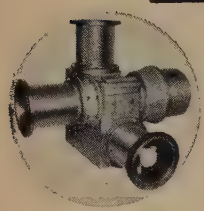
Type	Frequency Range (mc)	Line Size
12	2.5-250	Type N
11-Q	30-400	Type N
11-PS	180-1100	Type N

SLOTTED LINES

- *Residual swr under 1.010*
- *Rated error in detected signal under 1.005*
- *Available with a wide variety of tapered reducers*

Type	Frequency Range (mc)	Impedance (ohms)
1026-13	50-3000	50 or 75
1026-8	75-3000	50 or 75
1026-6	100-3000	50 or 75
1026-4	150-3000	50 or 75
1026-2	300-3000	50 or 75

COAXIAL SWITCHES



- *High power ratings; swr under 1.06*
- *Pressurized*
- *Motor-driven and manually operated models*

Type	Frequency Range (mc)	Line Size
1038	0-450	6⅛"
1136	0-500	3⅛"
Very high peak power models for radar applications		
1038-HV	0-450	6⅛"
1136-HV	0-500	3⅛"

INSTRUMENT LOADS

- *High stability; very low swr*
- *Nearly all transmission line sizes*

Type	Frequency Range (mc)	Line Size	Max SWR
1108B	0-1100	Type N	1.02
2120	0-1000	⅞"	1.03
1112	0-1000	1⅝"	1.03
1110	0-650	3⅛"	1.03

HYBRIDS

- *Very broad band*
- *Very low residual unbalance*

Type	Frequency Range (mc)	Max. SWR	Residual Unbalance (db)
1027-K	60-120	1.4	−50
1027-L	120-240	1.4	−50
1027-M	240-480	1.5	−50
1027-N	480-960	1.6	−50
1098	960-1600	1.6	−40
1102	1600-2400	1.5	−40
1104	2400-3600	1.5	−34
1100-K	60-120	1.4	−55
1100-L	120-240	1.4	−55
1100-M	240-480	1.5	−55
1100-N	480-960	1.6	−55
1099-N	800-960	1.2	−50
1099-O	975-1175	1.2	−50
1024	TV Channels 2-13	1.05	−50

OTHER PRODUCTS

TAPERED REDUCERS
LINE STRETCHERS
DIPLEXING FILTERS
VOR ANTENNAS
TV BROADCASTING ANTENNAS — directional and omnidirectional
ADJUSTABLE MATCHING NETWORKS
IMPEDANCE STANDARD LINES

ANTENNA SYSTEMS — COMPONENTS — AIR NAVIGATION AIDS — INSTRUMENTS

AMCI ALFORD *Manufacturing Company*
299 ATLANTIC AVE., BOSTON, MASS.

CIRCLE READER SERVICE CARD 12

INDUSTRY NEWS

1960 PGMTT SYMPOSIUM

The 1960 Symposium of the Professional Group on Microwave Theory and Techniques will be held May 9-11 at the Hotel del Coronado, Coronado, (San Diego) California.

This yearly conference, sponsored by the Professional Group on Microwave Theory and Techniques, provides engineers and scientists an opportunity for an interchange of ideas and information in the basic and applied field of microwaves.

A first call for papers in the areas related to microwave components, systems and physics has been issued. One hundred word abstracts in triplicate and 500 word summaries in triplicate should be sent before January 15, 1960 to:

Dr. David B. Medved
Chairman, Technical Program
1960 PGMTT Symposium
Convair,
A Division of General Dynamics
Mail Zone 6-172
P. O. Box 1950
San Diego 12, California

Advance information on the Symposium may be obtained by writing H. B. Babitz, 3701 Oleander Drive, San Diego California.

• • •

OCTOBER PGED MEETING

A group of invited papers dealing with the latest advances in semiconductor and microwave components will be presented on opening day of the Fifth Annual Electron Devices meeting to be held by the Professional Group on Electron Devices (PGED) of the Institute of Radio Engineers (Oct. 29 and 30) at the Shoreham Hotel, Washington, D. C.

Dr. John A. Hornbeck, Bell Telephone Laboratories, Murray Hill, N. J., technical program chairman for the meeting said that a special session of invited papers will seek to "explain and appraise recent trends in electron tube and solid-state device technology.

The papers will be delivered by:

Dr. Robert N. Hall — General Electric Research Laboratory in Schenectady "Tunnel Diodes"

Prof. Hubert Heffner — Electronics Research Laboratory, Stanford University "Competing Means of Achieving Low Noise"

Dr. Ian M. Ross — Bell Telephone Laboratories "Functional Devices."

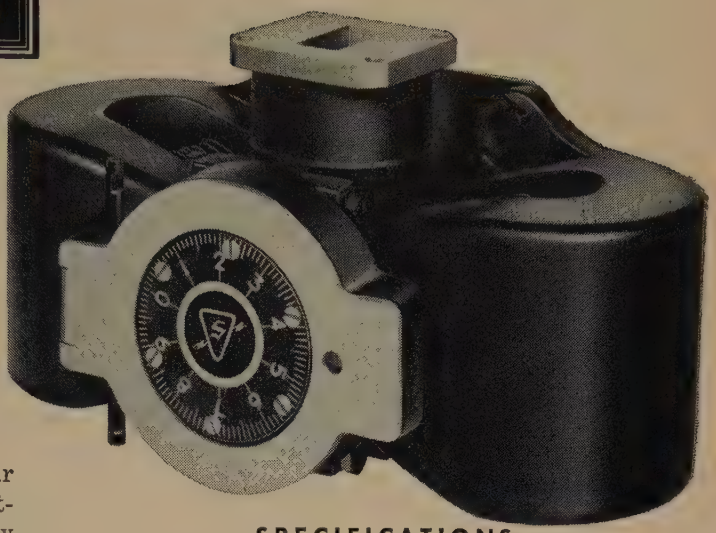
The PGED is an association of members of the Institute of Radio Engineers with professional interest in the research, development, design, and application of electron tubes and solid-state devices, as well as in scientific, technical, industrial and other activities that contribute to the field.

(*Continued on page 22*)

Microwave Component News from SYLVANIA

New line of X-band magnetrons, servo-tunable over 1100 mc

M4164, M4193, M4163
cool without special ducts

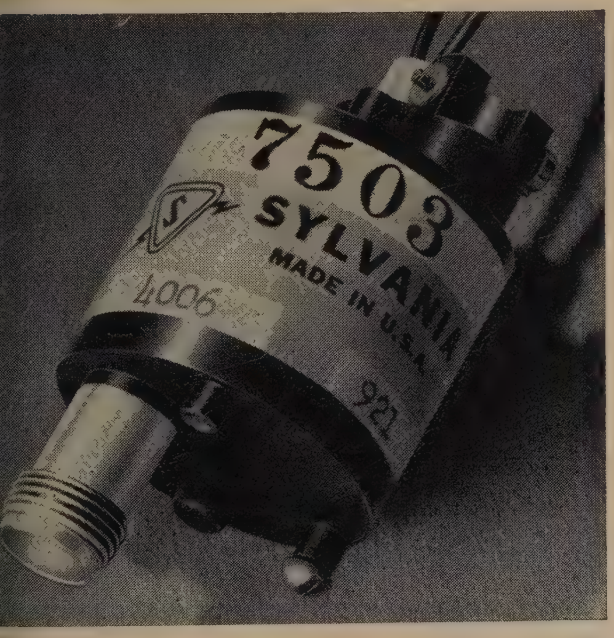


ese three rugged new magnetrons, like the familiar 74 and 7006, feature the same size, accessible mount- points, and high reliability of the fixed-frequency 50. The unique tapered-pin tuner, already proven hly successful in severe applications of the 6874 and 96, has been incorporated in this line. Servo-tuning hout a special oversized gear box and no change in line is available in all five types on request. Easy er-dial readability and ruggedness, flexibility of er location, and standard through-bolt lug mounting m the top are regular benetfis featured by Sylvania. mismatch at full power and atmospheric pressure is de possible by a new window design. Fin placement mits cooling without special ducting.

SPECIFICATIONS

TYPE	FREQUENCY RANGE, MC	AVER. POWER AT 1 US MIN., WATTS	RRV KV/US	STATUS
M4163	8500-9600	190	180	Pilot production
M4164	8500-9600	200	200	Pilot production
M4193*	8500-9600	200	225	Pilot production
6874	8800-9400	190	180	In production
7006	9000-9600	190	225	In production

*Has leading edge mode stability specification.



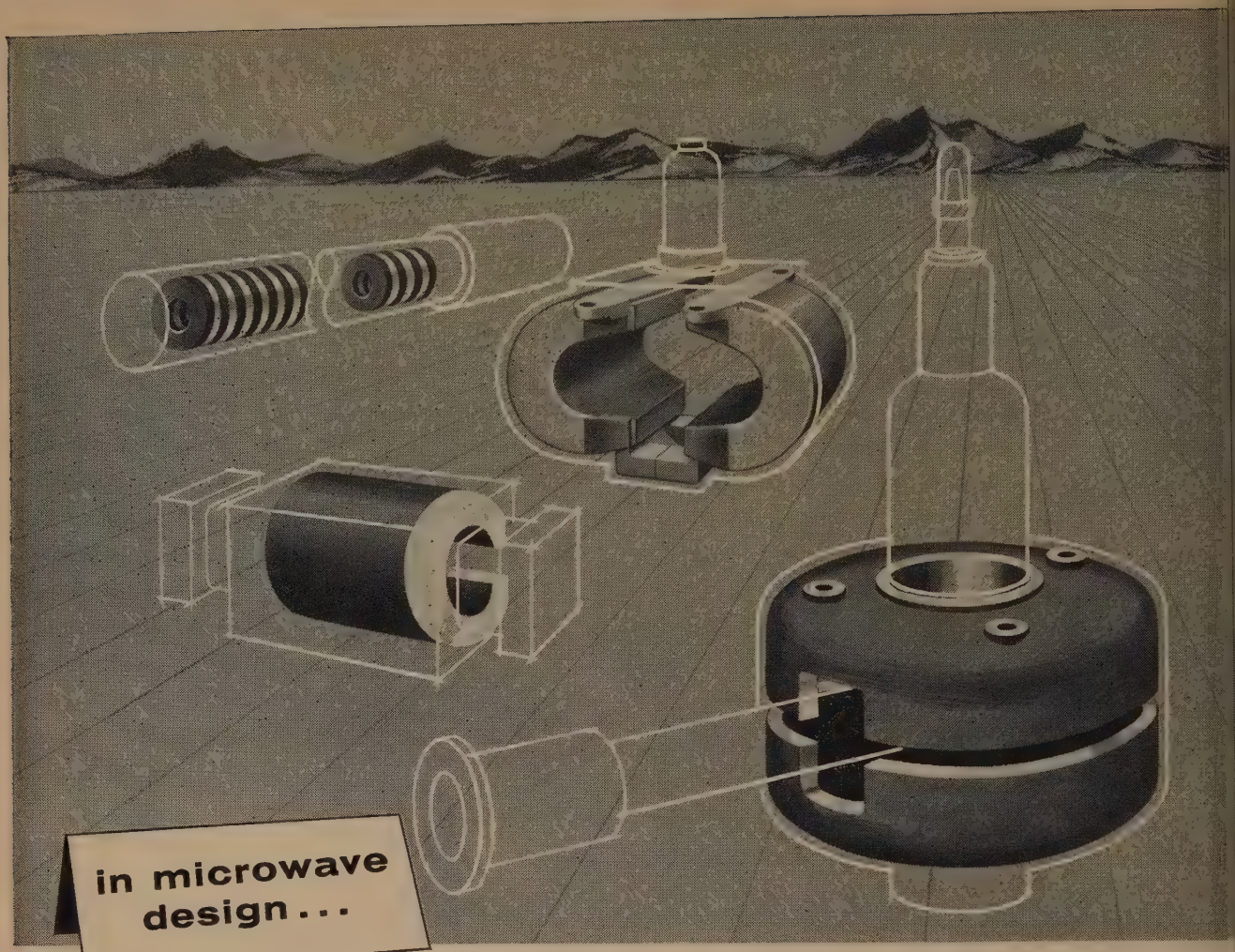
New ruggedized beacon magnetron delivers 100 watts peak power

Addition of TNC connector improves output

Sylvania type 7503 is a beacon magnetron specially ruggedized for missile applications. An advanced-design version of the 7098, the new tube delivers a minimum peak power of 100 watts and employs a TNC output connector which increases efficiency. Since the connector feeds into a broad-band coupler, it eliminates the need for adjusting for optimum power when the frequency is changed. The tubes withstand a 500 g, 1 millisecond shock. Additional ruggedness has been designed into the mounting bracket and tuner structure to increase the outstanding reliability of the tube.

For more information
write your nearest Sylvania tube sales office or
Sylvania Electric Products Inc.,
Special Tube Operations,
500 Evelyn Ave., Mountain View, Calif.

SYLVANIA
Subsidiary of
GENERAL TELEPHONE & ELECTRONICS



Put PERMANENT MAGNET SPECIALIST on your development team

Application of permanent magnets in microwave devices has resulted in vastly improved performance, lower costs and greater stability. Since the early days of micro-wave research, The Indiana Steel Products Company magnet design engineers have worked closely with leading manufacturers, providing expert help in developing special-purpose permanent magnet assemblies for such applications as radar magnetrons, backward wave oscillators, pm-focus traveling wave tubes and load isolators.

A discussion with permanent magnet specialists at The Indiana Steel Products Company may be just the stimulus your new design efforts need — or perhaps you'll find a way to improve your present products. In any case, you can be sure of this — *nobody knows permanent magnets like Indiana.* And, because Indiana produces *all* permanent magnet materials, Indiana design engineers are well qualified to recommend the *one* best material for your design. Why not call in an Indiana man today?

THE INDIANA STEEL PRODUCTS COMPANY
VALPARAISO, INDIANA

WORLD'S LARGEST MANUFACTURER
OF PERMANENT MAGNETS

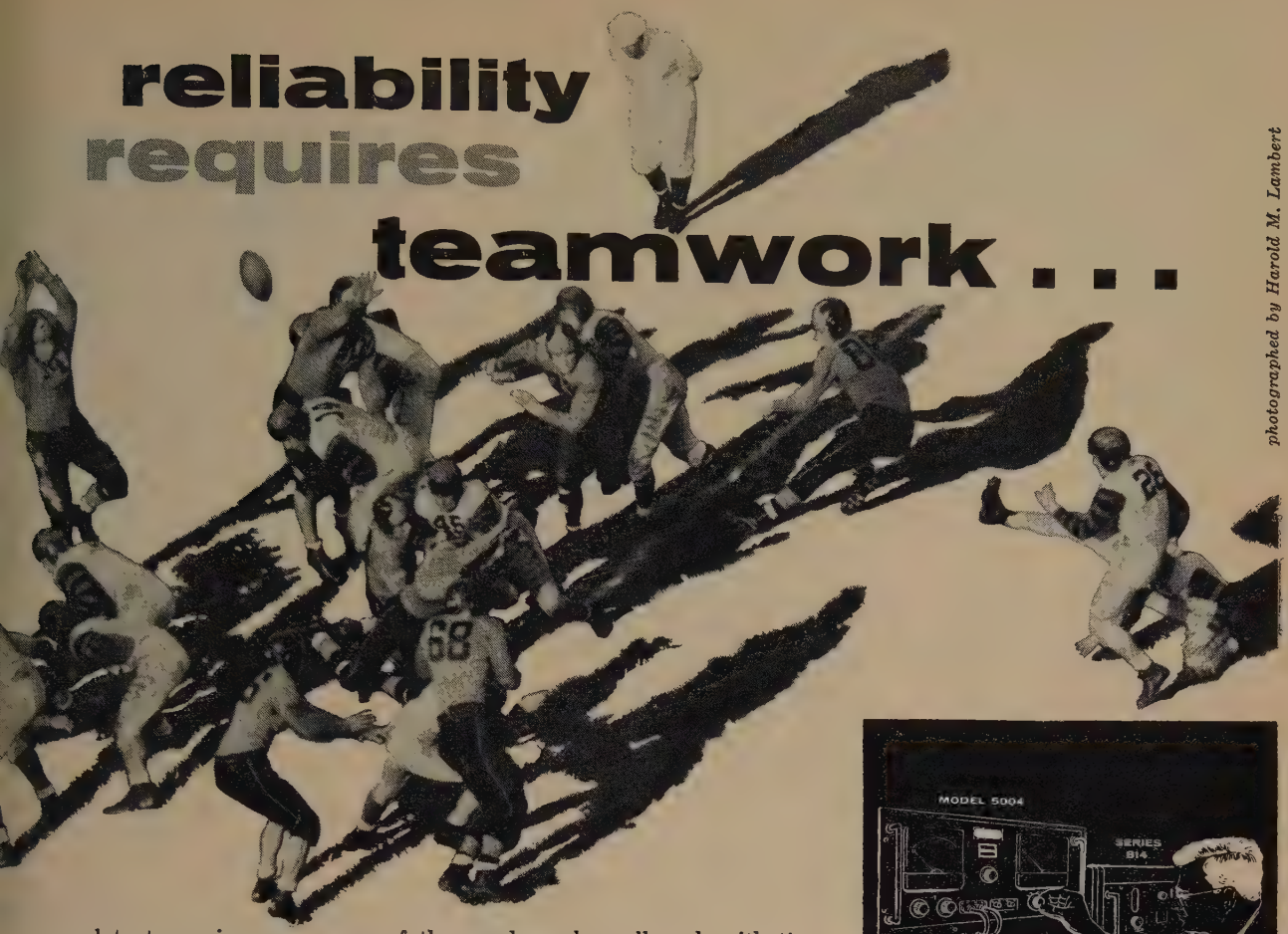
INDIANA PERMANENT MAGNETS

IN CANADA: The Indiana Steel Products Company of Canada Limited, Kitchener, Ontario

FREE DESIGN MANUAL

Write TODAY for important free, new catalog for micro-wave design engineers — "Alnico Load Isolator Magnets," which describes shapes and sizes, magnetic properties and performance characteristics of this complete line of Indiana permanent magnets. Ask for Catalog No. 20 Q10

reliability requires teamwork . . .



photographed by Harold M. Lambert

a complete team, in every sense of the word, works well each with the other — yet each individual is a specialist; with a specific job to do. They are many with but a single purpose — reliable precision performance.

In Microwave Instrumentation, LFE fields the industry's most complete team for ultra-stable microwave generation and measurement. Each instrument compatible with the other . . . each a star in its own right. Reliability has been tried and proven in all fields of microwave work for over seven years. For complete information on the microwave industry's most complete line-up write today!

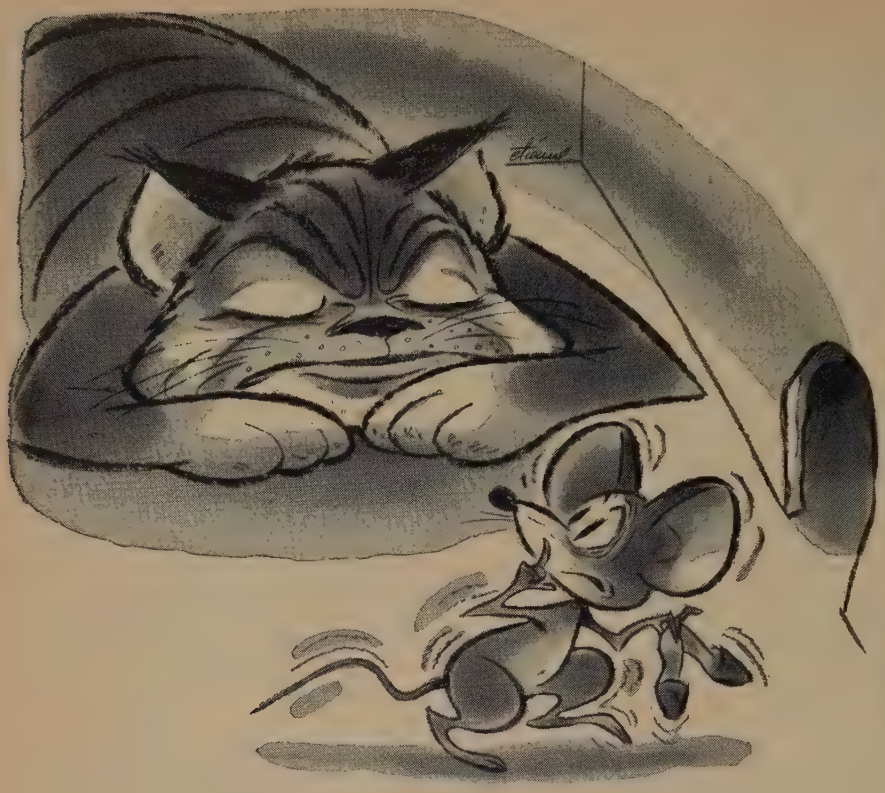
SERIES 814
Microwave Oscillators
High power (from 20 milliwatts up to 1 watt), ultra-stable, tunable oscillators. 24 models span the microwave spectrum from 2500 to 26,000 mc. Special models available to 60 kmc. Average short term stability (residual) is 5 parts in 10^8. Average long term stability is one part in 10^6.

MODEL 5010
S-Band Exciter
Highly stable, crystal controlled CW signal source. Provides sufficient power over a frequency range of 2670-2870 mc to drive high power klystron amplifiers. Long term stability: ± 100 kc per 25 hours. Short term stability: ± 1.5 cps peak deviation per 4 millisecond interval, 1.2 cps max. X-Band Exciter also available.

MODEL 5004
Microwave Stability Tester
Measures drift and f.m. in frequency bands between 1120 mc and 10,800 mc — at 30 mc and 30 kc to 230 kc. S, L, C, X, XA and K heads available. Phenomenal accuracy — measures S-band deviation to less than 2 cps, X-band deviation to 10 cps. Outputs may be viewed on oscilloscope or spectrum analyzer.

MODEL 5009
Microwave Stability Tester
Measures drift and f.m. in frequency bands between 10 mc and 13,800 mc — at 30 mc and 30 kc to 70 kc. All readings may be taken instantly and monitored continuously. Accurate from 0.1 to 0.2 cps at 30 mc and second I.F. At R.F. it will not limit the measurement of stable oscillators capable of one cps peak deviation.

LABORATORY FOR ELECTRONICS, INC.
INSTRUMENTS AND COMPONENT SALES
75 PITTS STREET, BOSTON



When low noise level is vital...

Microwave Associates – developers of the famous low noise "E" series silicon diodes – now brings you

COAXIAL DIODES

with noise figure improvement of:

1.5 db at 16 KMC with the **1N78B**
3 db at 25 KMC with the **1N26A**
3 db at 35 KMC with the **1N53B**

Simple substitution of these new coaxial diodes for existing types should improve your overall receiver noise figures as shown. No holder or IF amplifier redesign is required to realize system improvements with these improved versions of the standard coaxial mixer diodes.

Microwave Associates is now delivering these diodes as well as the new tripolar types. Typical of these broadband types is the 1N630 which covers the frequency range of 1 KMC to 12.4 KMC.

Our factory or the sales representative nearest you will gladly handle your specific requests by wire, phone, or mail.

CIRCLE READER SERVICE CARD 16

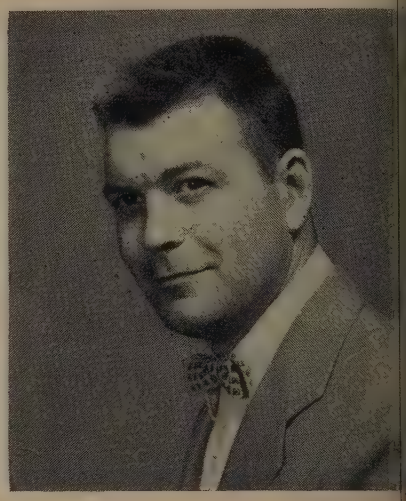
MICROWAVE ASSOCIATES, INC.

BURLINGTON, MASSACHUSETTS • BRowning 2-3000

Industry News

(*Continued from page 18*)

B. J. WARREN



Michael G. Stratton, President of plied Dynamics Corporation, Nat Massachusetts, announces the appointm of Bernard J. Warren as Sales Mana This appointment coincides with the chase by Applied Dynamics of the tron-Itek Microwave Spectrum Analy and related RF Heads with which W ren has been associated for many year both Vectron and Itek. In his new pacity, Warren will be responsible for sale of Applied Dynamics' complete p uct line. Stratton stated that the Mi wave Spectrum Analyzer is the in step in setting up an Instrument Divis heavily orientated in the microwave fi

• • •

ELECTRONIC SPECIALTY CO. EXPANDS

Recent acquisitions and expansion Electronic Specialty Co. have resulted some reorganization and delegation of sponsibilities in all Divisions of the co pany — the most recent being the pointment of Vern Landis Jr. as Sa Manager for the Radiating Systems Di sion. In making this announcem L. W. Burn, General Manager of E tronic Specialty Co., states that w Landis assumes this new post, Ted Duay will continue as Sales Manager the Avionics Division.

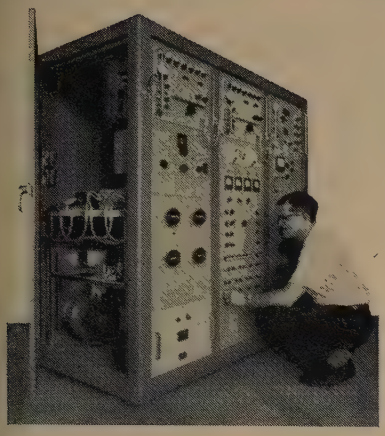
The Radiating Systems Division ESCO is housed in the parent building 5121 San Fernando Road, Los Angeles California and for several years has b a prominent design and production sou for antennas, antenna arrays, coa switches, power dividers, filters and ot components as well as complete ante systems for the aircraft industry.

Landis was formerly Vice-President General Manager of Tamar Electro and prior to that was associated w Douglas Aircraft for six years as H of the Antenna Research and Developm

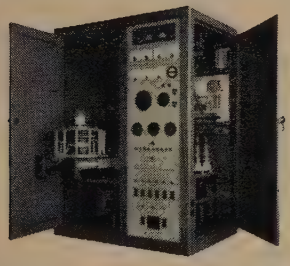
(*Continued on page 46*)

WORK IN PROGRESS AT LEVINTHAL

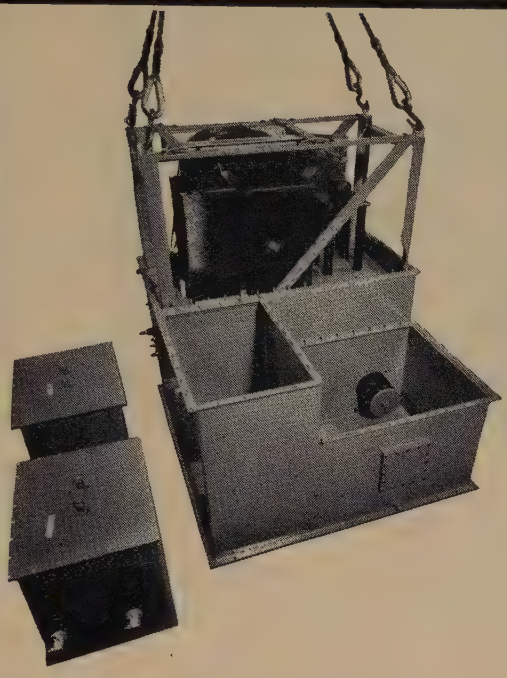
Among the various projects on the work docket in the Levinthal Stanford Industrial Park plant, these samples give a hint of the breadth of capabilities existing here.



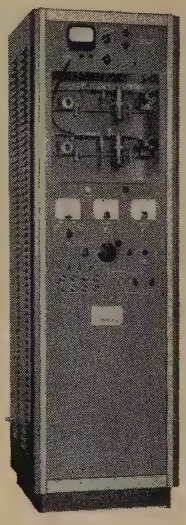
Model 229T. Built for Rome Air Development Center, this combination signal source covers the spectrum of 1 to 11 kmc in four bands. Useful for component-laboratory or antenna-range application, the instrument features internal pulse, square-wave, and frequency modulation; includes extensive provisions for stability. Separate units for each band are also available as Model 231T.



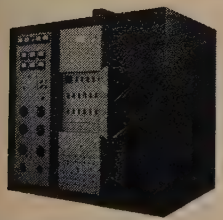
Model 74T. Destined for scatter-communications use, this 1-kw transmitter contains an Eimac 3K2500SG klystron and functions over the band 1700 to 2400 mc. Unit, complete as shown, offers convenience of having klystron on drawer-type mounting. Delivery will be made to Westinghouse.



Special pulse-transformer assembly for Litton Industries' Power-Tube Division combines standard Levinthal 1Q3 Pulse-Current Transformer (lower right) with specially designed 250-kv 234-amp 17:1 klystron pulse transformer, rated at 58.5 megawatts peak and 193 kw average power. Tank has provision for installation of peak-reading voltmeter. At left are Levinthal 3-henry 4.5-amp 35-kv (peak) charging chokes for the same installation.



Model 99P. An 18- to 40-kmc 1-mw signal source for Douglas Aircraft Company. Designed for countermeasures, this instrument also serves as a general-purpose laboratory device.



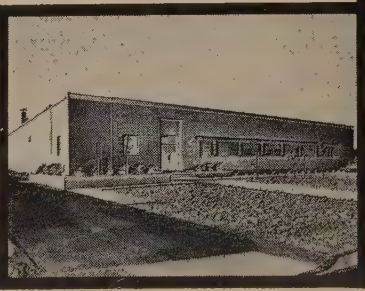
Model 250T. Here is a combination 0- to 75-kv 250-ma klystron beam supply and 0- to 44-kv modulator supply for Eitel-McCullough Inc. to use in testing X757 klystrons. On the same contract with Bendix Radio, Levinthal is producing 12 MIL-spec modulators, also for Air Force DEWline Sentinel radar.

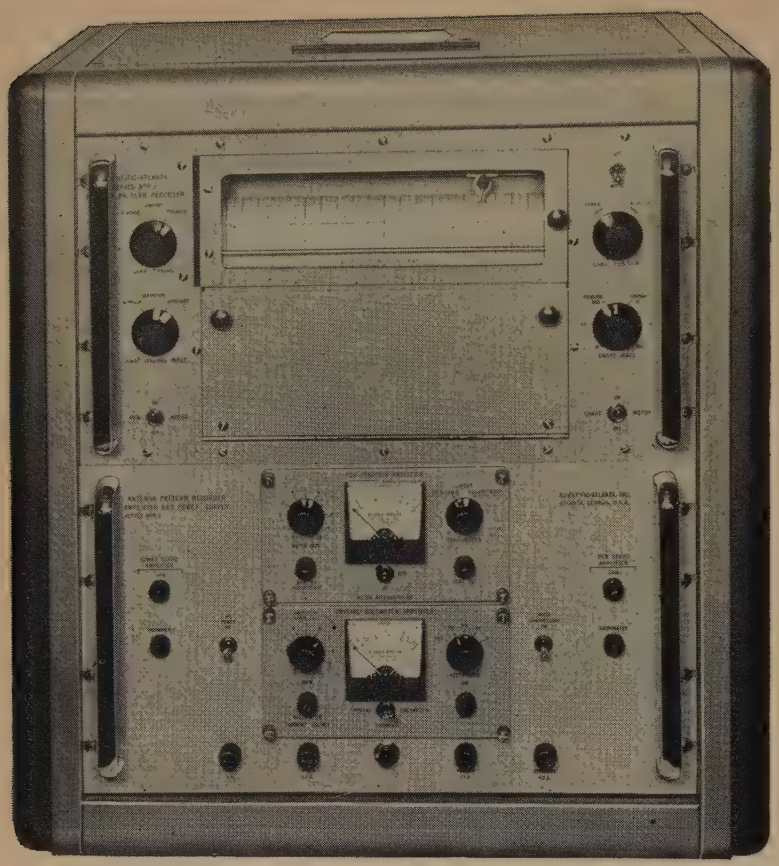
LEVINTHAL ELECTRONIC PRODUCTS, INC.

Stanford Industrial Park Palo Alto 7, California

Major products of the Levinthal Equipment Division are transmitters, modulators, high-power pulse transformers, power supplies, and related accessories for application to radar, missile guidance, communications, and tube development. Ask us for details or bring us your special problems.

If you think you would find designing equipment of this general type fascinating, maybe you should consider the possibility of coming to work at Levinthal. Get a resume shipped off to us today.





THE NEW S-A

ANTENNA PATTERN RECORDER

** Noise suppressor for better S/N ratio * Bolometer burnout protector * DB meter for signal monitoring * Automatic single chart cycle advance*

Scientific-Atlanta's new series of rectangular antenna pattern recorders bring you new standards of performance, reliability and flexibility.

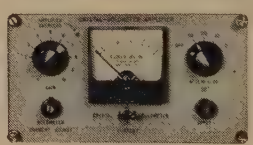
Compare these key features

Writing speed of better than 40 inches per second • Log, linear, or square root pen response obtained with plug-in balance pots • One electronics system drives both polar and rectangular recorder heads • Overload indicator to prevent amplifier saturation • 60 db dynamic range system available • Chart scale expansion of 1:1, 6:1, and 36:1 • Page size recordings optional at extra cost • 100 db gain in bolometer amplifier • Lighted chart • Improved pen mechanism • DC input pre-amplifier available • Plug-in selective filter • Simplified controls.

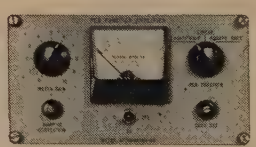
PRICES, Series APR-20 Rectangular Antenna Pattern Recorders

APR-21 linear, $4100 — APR-22 logarithmic, $4300 — APR-23 linear, logarithmic, $4700 — APR-24 linear, square-root, $4700 — APR-25 linear, logarithmic, square-root, $5300.

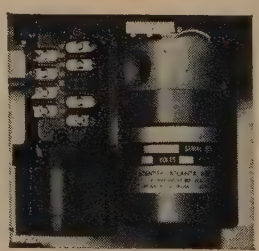
THESE PLUG-INS MEAN FLEXIBILITY AND EASY SERVICE



New high gain, low noise bolometer — crystal amplifier



New pen function amplifier



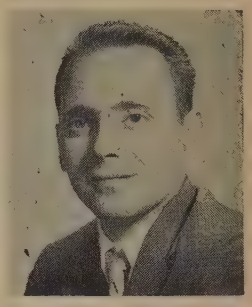
New pen balance potentiometer

Call your nearby S-A engineering rep for a demonstration and complete technical information or you may write directly to the factory. Please ask for data sheet 6810

SCIENTIFIC-ATLANTA, INC.

2162 PIEDMONT ROAD, N.E. • ATLANTA 9, GEORGIA

CONTRIBUTORS IN THIS ISSUE



'ILLIAM COHEN was born June 18, 1927 in Irvington, New Jersey. Schooling at the Newark ollege of Engineering was interrupted in 1945 for a period in the Navy. Upon return to the ewark College of Engineering, he obtained a B.S. in E.E. in 1948 and an M.S. in E.E. in 1952.

Mr. Cohen was employed by the U.S. Army Signal Corps Engineering Laboratories, Fort onmouth, N.J. from July 1948 to January 1956 where he worked on V.H.F. and U.H.F. fre- ency modulated radio relays, high power H.F. transmitters and antennae for fixed and rotary ng army aircraft. From February 1956 to September 1956 Mr. Cohen was employed by the ational Security Agency, Washington, D.C. where he worked on the design and development low noise figure receiving equipment.

Since September 1956, Mr. Cohen has been employed by Stavid Engineering Incorporated, esently as a consulting Project Engineer. His work at Stavid has been largely in the fields of M.-C.W. and Doppler cooperative and non-cooperative scoring systems and conventional and onopulse radars.

MR. ALBERT L. HEDRICH joined Weinschel Engineering in July 1957 as Chief Engineer and Vice President.

Prior to his association with this company, he was a Section Chief with the Diamond Ordnance Fuze Laboratories and the National Bureau of Standards. Mr. Hedrich was the Head of a Technical Section in the Supporting Research Laboratory of the Diamond Ordnance Fuze Laboratories, and was engaged in work in the fields of high frequency transmission, frequency modulation, ultrasonics, optics and temperature measurements.

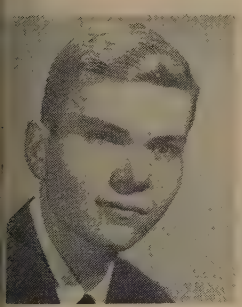
Mr. Hedrich has done graduate work in the fields of Electrical Engineering and Physics at the George Washington University, University of Maryland, and Johns Hopkins University.

Mr. Hedrich is a Senior Member of the Institute of Radio Engineers, a registered Professional Engineer in the District of Columbia, and past Chairman of the Washington Chapter of the Professional Group on Instrumentation of the I.R.E.

VILLIAM A. SMITH was born in Washington, D.C. on 28 August 1926. During World War , he served in the U.S. Navy. He received the B.S. and M.S. degrees in Electrical Engineering om the Massachusetts Institute of Technology (1948) and from Northeastern University (1957) spectively. He is married and is the father of three children.

In 1948, Mr. Smith joined the Raytheon Company where he became engaged in the de- gn and development of high power magnetron oscillators and advanced crossed-field devices. ppointed to his present position in 1956, he now supervises a number of Amplitron tube de- elopment programs at the Spencer Laboratory in Burlington, Mass.

He is a senior member of the I.R.E. and is currently serving as Vice-Chairman of the oston Chapter, I.R.E.-P.G.E.D.



C. MARTIN STEINMETZ was born on August 22, 1936 at Newark, New Jersey. He received a Bachelor of Electrical Engineering degree from Yale University in 1958. In the summer of 1957 he worked at Stavid Engineering, Inc. doing design work with low noise amplifiers and automatic frequency control systems. Upon graduation he returned to Stavid where he worked on vacuum tube and transistor receivers for an airborne radar set. He also completed a system analysis for this radar set and worked on an analysis of pulse compression radar techniques. He has designed wideband limiting amplifiers, special purpose video amplifiers and has worked on missile scoring systems.

Mr. Steinmetz is a member of the I.R.E. and is currently on a leave of absence from Stavid doing graduate work at Yale University.

RANK A. ZAWADA was born in Thompsonville, Connecticut on April 30, 1924. He received is B.E.E. degree from Indiana Tech. in 1949 and is doing Graduate work at Northeastern Jniversity, Boston, Massachusetts.

In October, 1949, Mr. Zawada joined the Raytheon Power Tube Division and is presently ngaged as a Project Engineering Section Head in the High Power Tube Laboratory, at the Raytheon Spencer Laboratory, located in Burlington, Mass.

At Raytheon, Mr. Zawada has been engaged in the development of tunable magnetrons and Amplitrons. Raytheon has filed patents of his innovations in microwave tubes.

Mr. Zawada is a member of the IRE and the IRE-PGED.

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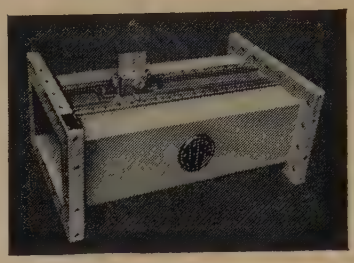

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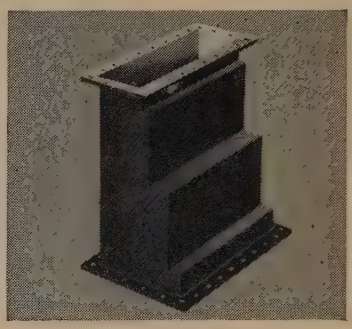

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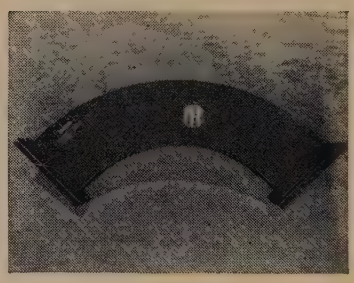

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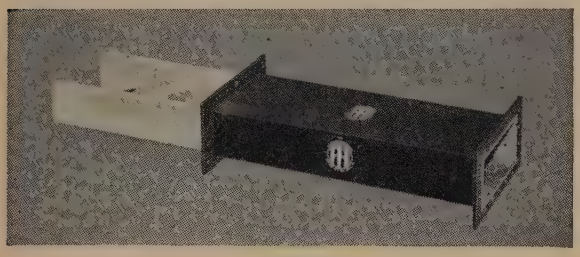

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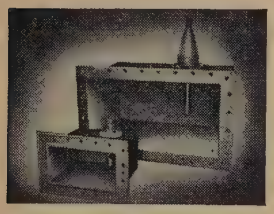

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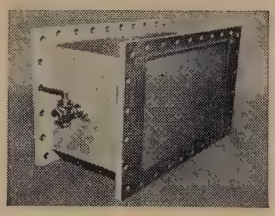
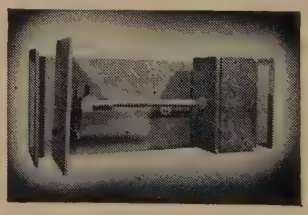


Gas barriers

Slotted lines



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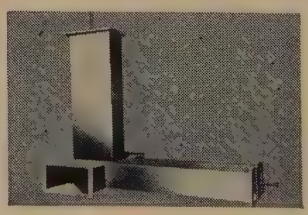
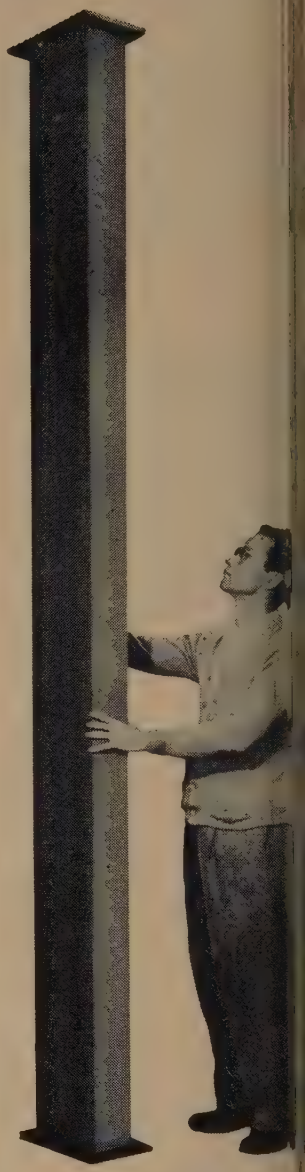


E-H plane tuners



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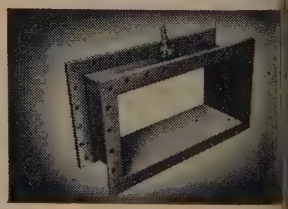

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AMPLITUDE—AND PHASE—SENSING MONOPULSE SYSTEM PARAMETERS

WILLIAM COHEN
and
C. MARTIN STEINMETZ

STAVID ENGINEERING, INC.
PLAINFIELD, NEW JERSEY

n analysis of amplitude- and phase-sensing sum-and-difference onopulse systems is made in an attempt to specify the effects rtain parameters have on system performance. The effects of pre-mparator voltage unbalance, phase shifts and post-comparator base shifts are shown and compared for each type of sensing stem. Since the basic difference between a phase-sensing and nplitude- sensing monopulse system lies in the antenna configura-on, major attention is given to the antenna and the microwave sembly which produces the monopulse additions and subtractions. o complete the evaluation, the parameters which affect the receiv-g equipment performance have also been developed. Equations scribing the performance of the systems have been derived and stem evaluation curves have been plotted using these equations.

PART I

troduction

The intent of this paper is to give the reader an under-nding of the operation of amplitude- and phase-nsing sum-and-difference monopulse systems. This derstanding may be enhanced by examining the most portant parameters and the manner in which they ect system performance. To establish these parameters d their operational significance in the clearest form, tain simplifying assumptions are made to reduce the thematical complexity. In such cases where the as-ned functions closely resemble the actual radar char-eristics, the curves plotted herein may be used to edict its system performance. Where the assumptions not valid, the reader may make a similar analysis substituting the appropriate radar characteristics.

Monopulse Versus Conventional Radar

The transmitting function of a sum-and-difference monopulse system is the same as for a conventional radar; that is, a short burst of energy is radiated for every pulse cycle—illuminating the area included within the antenna beamwidth. In a monopulse system the transmitted beamwidth is that of the sum antenna pattern; and due to reciprocity, this pattern is obtained by inserting the transmitter output into the r.f. sum channel. Physically this is accomplished using a duplexer which may consist of two short slot hybrids and a dual TR tube. During the transmit period the TR tubes are fired and the hybrid arrangement causes all the transmitter energy to flow in the port feeding the sum channel. After the transmitted pulse, the TR tubes deionize, and the hybrid arrangement causes all the received energy to flow in the port feeding the receiver.

The major difference, however, between the two radar systems lies in their receiving functions. The received signal in a basic monopulse system is utilized by two channels — a sum and a difference channel, whereas one

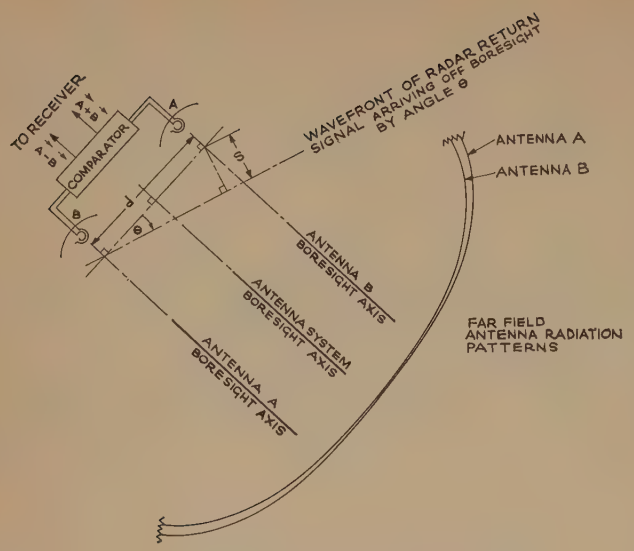


Figure 1 — Phase-sensing antenna configuration.

channel is used in the conventional radar system. The sum and the difference channels described herein may be derived from either the azimuth or elevation plane; the analysis is the same. The sum channel is similar in operation to a conventional radar receiver channel where a maximum signal level is obtained for radar return signals arriving along the boresight axis of the antenna; and, the degree of target resolution is determined by the antenna beamwidth. However, an opposite condition exists in the difference channel where a minimum signal level is obtained for radar return signals arriving along the boresight axis of the antenna. The antenna characteristics and the r.f. comparison circuitry shape the r.f. signal envelope in the difference channel such that this minimum signal level defines the lowest point of a deep, sharp null. Using this sharp null indication to precisely define the boresight axis of the antenna, permits the monopulse system to measure target angles much more accurately than conventional radar systems having the same antenna beamwidth.

An additional improvement, of lesser degree, obtained by using monopulse techniques is increased target resolution. This resolution improvement is achieved by subtracting the video envelope of the sum and difference channels in what is termed, "Monopulse Resolution Improvement Circuits." This subtraction produces a sharp target pulse having, generally, the inverted shape of the difference channel envelope. Since this pulse is much narrower than that obtained from the sum channel alone (or the conventional radar channel), greater target resolution is obtained in the sum-and-difference monopulse system over a conventional radar having the same antenna beamwidth.

A Comparison of Amplitude- and Phase-Sensing Antenna Systems

A phase-sensing antenna system having the required amplitude and phase characteristics is constructed using two or more antenna apertures separated by several wavelengths, see Figure 1. The antenna apertures, each having a single feed, produce identical radiation patterns which are symmetrical about their individual bo sight axes. Since the individual boresight axes parallel, the far field radiation patterns from such antenna system are almost overlapping; giving ess tially equal amplitude signals in each antenna for t gets included in their beamwidths. However, th will be a time or phase delay between the signals ar ing at the feeds of each antenna due to the spac between them for all return signals which are off of boresight axis ($\theta \neq 0°$). Thus, due to the phase ch acteristic of the received signals, the addition and s traction of the separated feed signals in the compara results in establishing a well defined system boresi axis; which is midway between and parallel to the dividual antenna aperture boresight axes.

An amplitude-sensing antenna system having the quired amplitude and phase characteristics is construc using a single antenna aperture having two or m closely spaced feeds, see Figure 2. However, in amplitude-sensing antenna system each of the clos spaced feeds produces a radiation pattern which is d placed from the antenna boresight axis. This displa ment angle is a function of the separation of the fe horn phase centers from the focal point of the ante aperture. Although the antenna patterns are identi they do not overlap as in the phase-sensing system. T displaced patterns do, however, intersect on the boresi axis of the antenna. Thus, for all radar return sign within the beamwidth of the antenna, except th arriving along the boresight axis, unequal signal a plitudes will be induced in the feeds. When the t signals are subtracted a null will be produced for o those return signals arriving along the boresight axis since the feedhorns have equal signal voltages o at $\theta = 0$. This subtraction of the feed signals in t comparator results in establishing a well defined syst boresight axis along the antenna aperture boresight a due to the amplitude characteristics of these signa Thus, both sensing systems produce a null in the diff ence channel for signals arriving along their boresi axis.

Comparator and Receiver

The sum and difference signal envelopes are produc

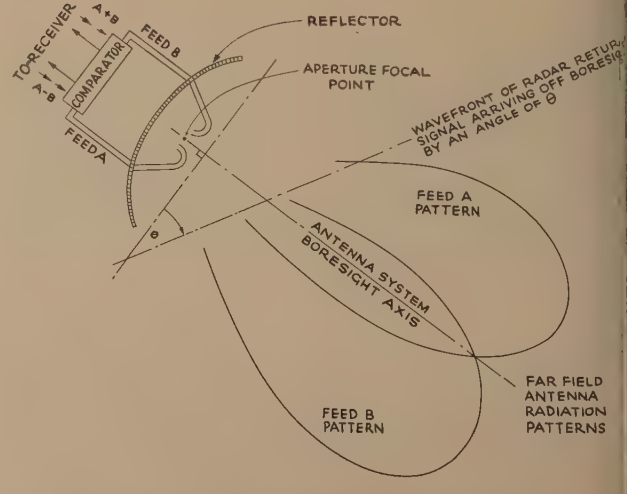


Figure 2 — Amplitude-sensing antenna configuration.

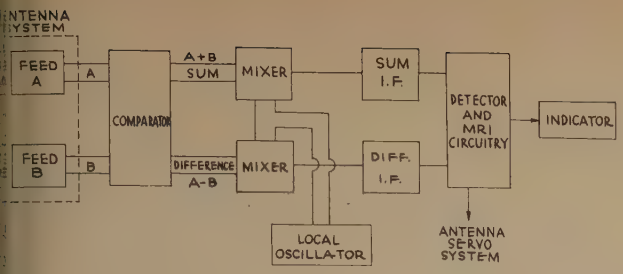


Figure 3 — Block diagram of a basic sum-and-difference monopulse system.

what shall be termed a "comparator." The comparator r a two channel basic monopulse system could consist in its simplest form, of a folded "T" hybrid. The m channel envelope is obtained by a vectorial addition, in the hybrid sum arm, of the received r.f. signals riving at the individual antenna system feeds. The fference channel envelope is produced by a vectorial btraction of these same r.f. signals in the difference orthogonal arm of the hybrid. A monopulse system r improving the resolution in both azimuth and elevation would use a more elaborate comparator, but its sic function would be essentially the same as described ove.

A block diagram of a basic sum-and-difference monopulse system is shown in Figure 3. The r.f. signals and eir associated envelopes coming from the sum and fference outputs of the comparator are heterodyned own, in the mixer, to an IF frequency where they are nplified in their individual IF channels and processed rough appropriate detectors and monopulse resolution provement circuitry.

Thus, it is seen that the two sensing systems differ ainly in the antenna configuration. Physically the mparator and the receiving equipment can be the same, t the exact function the comparator performs and e errors incurred by its use are quite different for each nsing system.

It should be noted here that in the forthcoming analysis only the received signal is being considered. It is sumed that the transmitted pulse will effectively spray" the area where the antenna is pointed with fficient energy to get a large return signal. In order derive usable and easily understood equations many arameters, such as noise, have been neglected, (see ference 5) but the following results may be extended rther to include these effects.

MPLITUDE-SENSING MONOPULSE SYSTEM

ntenna Parameters

It is assumed that the antenna voltage radiation pattern, produced by the displaced phase centers of the edhorns are described; for Lobe A by

$$\sin \frac{\pi (\theta - \theta_{NA})}{\epsilon} \qquad \theta_{NA} \leqslant \theta \leqslant \theta_{NA} + \epsilon$$

nd, for Lobe B by

$$\sin \frac{\pi (\theta - \theta_{NB})}{\epsilon} \qquad \theta_{NB} \leqslant \theta \leqslant \theta_{NB} + \epsilon$$

here $\theta =$ angle of the return signal wavefront with respect to the plane of the antenna aperture, see Figure 2.

$\theta_{NA} =$ angle at which the first null of lobe A occurs, in the domain $0° > \theta > -90°$.

$\epsilon =$ the beamwidth of each lobe (assumed to be the same for the two lobes) measured between the null points of the lobe.

$\theta_{NB} =$ angle at which the first null of lobe B occurs in the domain $0° > \theta > -90°$.

These expressions have been plotted in Figure 4 for a typical beamwidth and beam separation. A sine function was chosen to describe the amplitude radiation patterns instead of the more common $\frac{\sin X}{X}$ expression, since a good approximation of the actual patterns are obtained and it simplifies the expressions that will be derived.

The separation between the two lobes A and B can be defined as $\psi = \theta_{NB} - \theta_{NA}$. If the value of ψ is small, it can be computed approximately from the antenna parameters by the following expression:

$$\psi = \theta_{NB} - \theta_{NA} = K_p \tan^{-1} \frac{n}{f} \text{ (See Reference No. 2)}$$

where n is the distance between the feedhorn centers and f is the focal length of the dish in the desired plane. K_p is a constant which is a function of the size and shape of the paraboloid and the type of illumination used across the aperture. $K_p = .6$ for a small dish is a reasonable value.

If the individual radiation patterns of each horn are considered to be proportional to a sine function, the resultant sum channel and difference channel envelope patterns can be found. The sum envelope is the addition

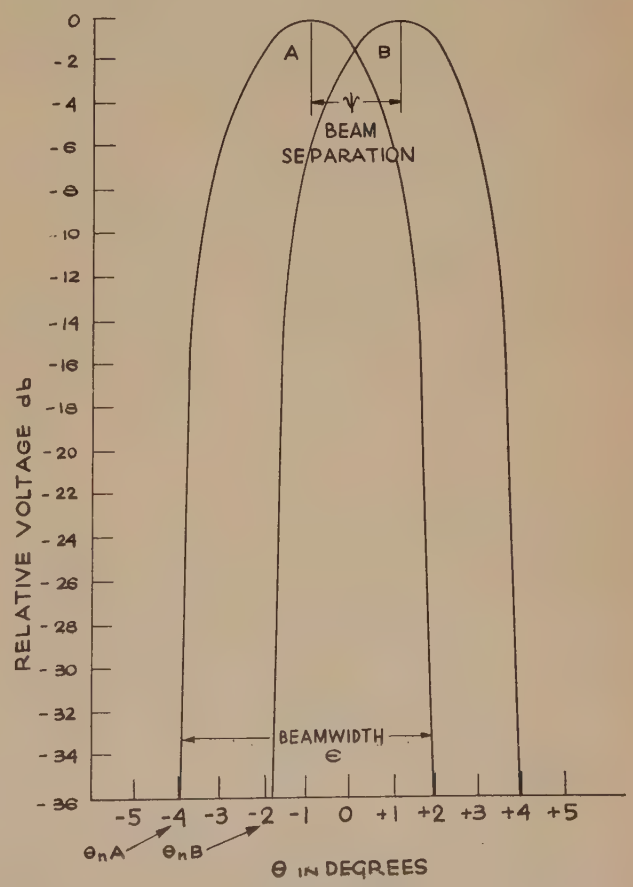


Figure 4 — Antenna lobes of an amplitude-sensing system assuming sine radiation patterns.

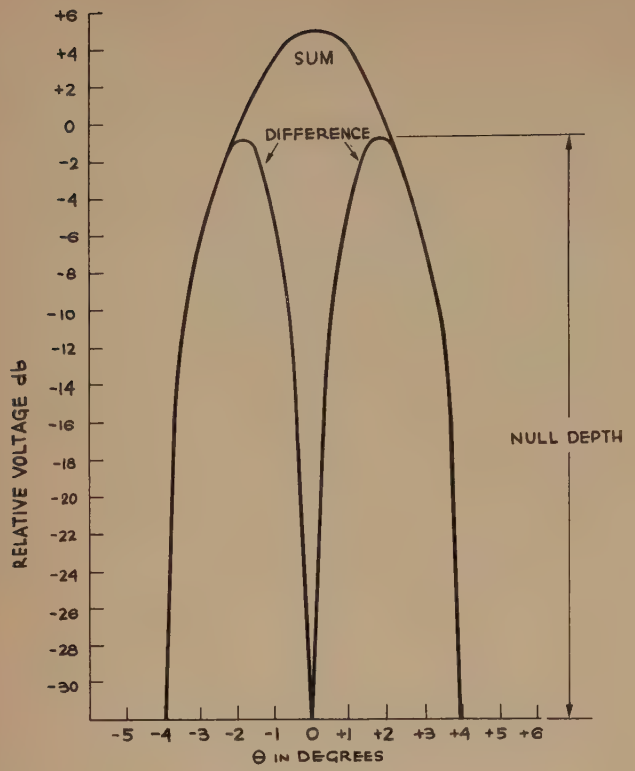


Figure 5 — Sum and difference envelope patterns for sine antenna patterns.

of lobe A and lobe B and the difference envelope is the magnitude of lobe A minus lobe B. These have been plotted in Figure 5.

The equations for the two lobes can be rewritten in a form which shows explicitly the antenna parameters of beamwidth, ϵ, and beam separation, ψ.

It can be seen from Figure 4 that

$\theta_{NA} = -\frac{1}{2}(\epsilon + \psi)$ and

$\theta_{NB} = -\frac{1}{2}(\epsilon - \psi)$

The expression for lobe A becomes

$$\sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 + \frac{\psi}{\epsilon}\right)\right]$$

$$-\tfrac{1}{2}(\epsilon + \psi) \leqslant \theta \leqslant \tfrac{1}{2}(\epsilon - \psi) \qquad (1)$$

and for lobe B

$$\sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 - \frac{\psi}{\epsilon}\right)\right]$$

$$-\tfrac{1}{2}(\epsilon - \psi) \leqslant \theta \leqslant \tfrac{1}{2}(\epsilon + \psi) \qquad (2)$$

Phase Shift Effects

It has been assumed that an equal phase signal is being received by both horns near the position of the null ($\theta = 0°$). However, as a result of some phase shift, γ, in the reflector, feedhorn and comparator, (which will be termed pre-comparator phase shifts) the voltages from the two lobes will not completely cancel at the boresight and the null level of the difference pattern will not be zero. For signals arriving on the boresight axis ($\theta = 0$) the magnitude of lobe A equals the magnitude of lobe B.

$$\sin\frac{\pi}{2}\left(1 + \frac{\psi}{\epsilon}\right) = \sin\frac{\pi}{2}\left(1 - \frac{\psi}{\epsilon}\right) = \cos\frac{\pi}{2}\frac{\psi}{\epsilon}$$

However, if there is a pre-comparator phase shift, γ, these signals are not 180° out-of-phase, and will produce a resultant output whose magnitude is:

$$\sin\frac{\pi}{2}\left(1 + \frac{\psi}{\epsilon}\right)\sqrt{2\ (1 - \cos$$

$$= 2\cos\left(\frac{\pi}{2}\frac{\psi}{\epsilon}\right)\sin\tfrac{1}{2}\gamma \qquad (3$$

The null depth is defined as the ratio of the level the null to the level at the peak of the difference patte as shown in Figure 5.

The peak occurs at

$$\frac{d}{d\theta}\sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 + \frac{\psi}{\epsilon}\right)\right] = 0$$

$$\frac{\epsilon}{2} \leqslant \psi < \epsilon$$

which is found to be $\theta = -\frac{\psi}{2}$. Substituting back in the lobe equation, a value of one is obtained which is t peak of the difference pattern when $\frac{\epsilon}{2} \leqslant \psi <$ Therefore, the null depth in db for large beam separtitons is $20\log_{10}\left(\frac{1}{2\cos\frac{\pi}{2}\frac{\psi}{\epsilon}\sin\frac{1}{2}\gamma}\right)$ (

in the domain $\frac{\epsilon}{2} \leqslant \psi < \epsilon$. However, when the bea separation is less than $\frac{\epsilon}{2}$ the null depth ratio chang because the peak amplitude is no longer one. It can seen from Figure 4 that the peak amplitude will alwa occur at θ_{NB} for the smaller beam separations. Hen the null depth in db for the domain, $0 < \psi \leqslant \frac{\epsilon}{2}$

is $20\log_{10}\left(\frac{\sin\frac{\pi}{2}\frac{\psi}{\epsilon}}{\sin\frac{1}{2}\gamma}\right)$ (

A family of curves showing the effects of phase shi γ, in the feed versus null depth as a function of t ratio of beam separation and beamwidth in the tw domains are given in Figure 6.

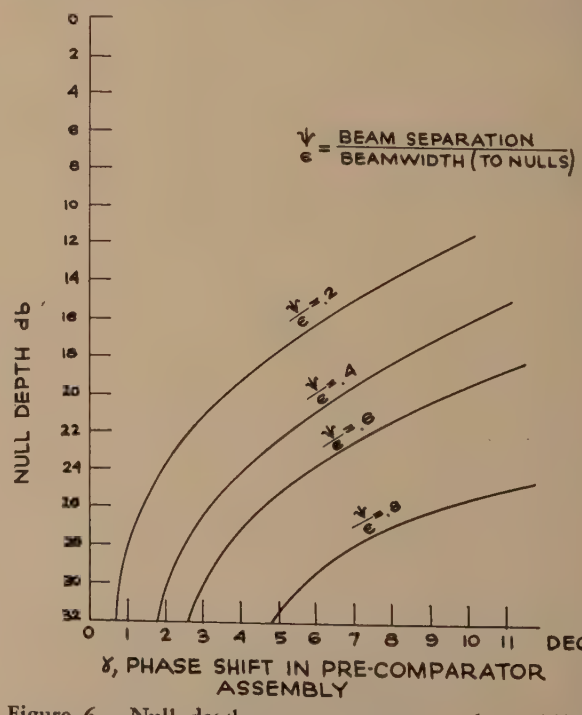


Figure 6 — Null depth vs. pre-comparator phase shift for amplitude-sensing monopulse system.

Since the null depth will affect the resolution of the dar system and its angle measurement precision, it is ost desirable to keep the null depth as deep and sharp possible. For a fixed tuned radar set, it is fairly easy

sultant outputs of the sum and difference signals are found vectorially. The magnitude of the difference channel was found to determine null depth, shown in equation (3). Its phase angle is found to be

$$\alpha_D = \tan^{-1} \frac{\sin\gamma \sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 + \frac{\psi}{\epsilon}\right)\right]}{\sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 - \frac{\psi}{\epsilon}\right)\right] - \sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 + \frac{\psi}{\epsilon}\right)\right]\cos\gamma} \tag{6}$$

milarly for the sum channel resultant signal output, its phase angle is found to be

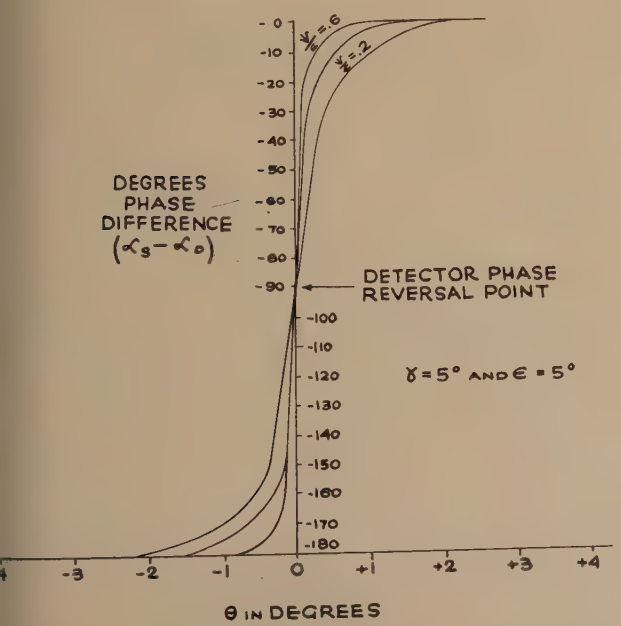
$$\alpha_S = \tan^{-1} \frac{-\sin\gamma \sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 + \frac{\psi}{\epsilon}\right)\right]}{\sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 - \frac{\psi}{\epsilon}\right)\right] + \sin\left[\frac{\pi\theta}{\epsilon} + \frac{\pi}{2}\left(1 + \frac{\psi}{\epsilon}\right)\right]\cos\gamma} \tag{7}$$

compensate for pre-comparator phase shifts, but in tunable radar system the phase shifts have to be kept nall over the frequency range. Figure 6 indicates that r good null depths the pre-comparator phase shifts ust be kept small, and for a given amount of phase ift in the feed, better null depths are obtained for e largest possible $\frac{\psi}{\epsilon}$ ratios. There is, however, a mit on how large the $\frac{\psi}{\epsilon}$ ratio can be made without preciably affecting the sum pattern. Using narrow amwidths and increasing beam separation will cause e sum pattern to flatten until eventually an undesirable p occurs in the pattern. Other factors such as the lowable phase center separation of the feedhorns and e dish size will also influence the engineering comomise required to obtain optimum system performce.

In addition to "filling-in" the null, pre-comparator ase shifts also result in a second order effect which is shifting of the phase crossover; or in other words, e antenna boresight indication. To demonstrate the gree of boresight shift, the phase angle of the re-

The phases of these two signals are compared in the receivers' amplitude-sensitive phase detector, which will be discussed later. The phase reversal point of the detector's output voltage is an indication of the antenna boresight. Any shift in this phase reversal point corresponds to an error in the pointing accuracy of the antenna.

Mathematically we can take the difference between the two phase angles to determine the response of the detector. Figure 7a and 7b show $(\alpha_S - \alpha_D)$, the phase comparison of the difference and sum channel resultant signals for selected values of γ and ϵ, with varying $\frac{\psi}{\epsilon}$ ratios; and, selected values of ϵ and $\frac{\psi}{\epsilon}$ with a varying γ. It can be seen that the phase of the compared signals reverses sharply when there is no pre-comparator phase shift, and becomes more gradual with increasing amounts of pre-comparator phase shifts or smaller $\frac{\psi}{\epsilon}$ ratios. But it should be noted that in all cases with no post-comparator phase shifts the reversal occurs on the boresight. However, as can be seen from Figure 8, post-comparator phase shifts change the point at which the curve intersects the detector phase reversal



gure 7(a) — Phase difference, $(\alpha_S - \alpha_D)$, vs. angle θ for various ratios of ψ/ϵ (amplitude-sensing monopulse).

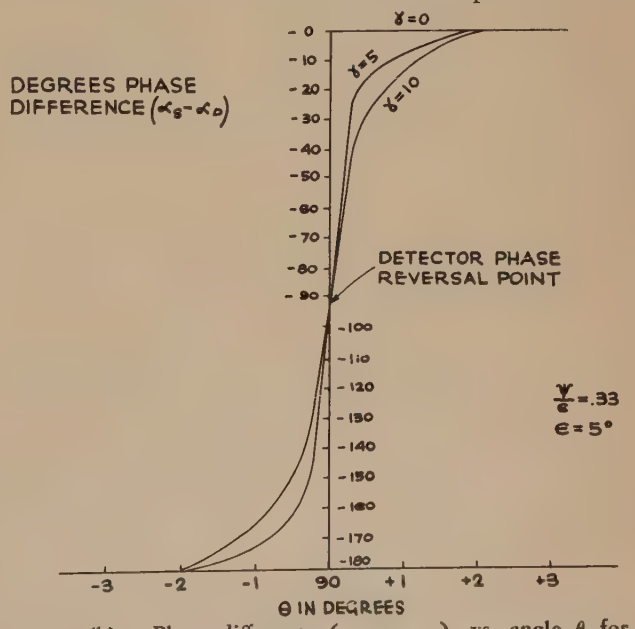


Figure 7(b) — Phase difference $(\alpha_S - \alpha_D)$, vs. angle θ for various pre-comparator phase shifts. (Amplitude sensing monopulse).

point. Hence, the combination of pre-comparator and post-comparator phase shifts will result in a change of boresight indication.

Voltage Unbalance Effects

As previously stated, the null point should occur at the antenna boresight ($\theta = 0°$) for symmetrical antenna patterns, when both lobes are of equal amplitude.

$$\sin \frac{\pi}{2}\left(1+\frac{\psi}{\epsilon}\right) = \sin \frac{\pi}{2}\left(1-\frac{\psi}{\epsilon}\right)$$

This equality, however, is contingent on a perfect voltage balance between the two channels, A and B. Should the signal levels be unequal, due to more attenuation in one channel than the other, the equation can be rewritten as

$$\sin\left[\frac{\pi\theta}{\epsilon}+\frac{\pi}{2}\left(1+\frac{\psi}{\epsilon}\right)\right] = K \sin\left[\frac{\pi\theta}{\epsilon}+\frac{\pi}{2}\left(1-\frac{\psi}{\epsilon}\right)\right]$$

where $K < 1$ represents the loss in relative voltage of the weaker signal channel. In order to solve this equation for θ_s which will now indicate the boresight shi

let $A = \frac{\pi\theta_s}{\epsilon}$, $B = \frac{\pi}{2}\left(1+\frac{\psi}{\epsilon}\right)$

and $C = \frac{\pi}{2}\left(1-\frac{\psi}{\epsilon}\right)$.

Thus the above equation may be rewritten as

$$\sin (A+B) = K \sin (A+C)$$

By grouping terms

$$A = \tan^{-1} \frac{K \sin C - \sin B}{\cos B - K \cos C}$$

The boresight shift as a function of voltage unbalanc

$$\theta_s = \frac{\epsilon}{\pi} \tan^{-1} \frac{K \sin\left[\frac{\pi}{2}\left(1-\frac{\psi}{\epsilon}\right)\right] - \sin\left[\frac{\pi}{2}\left(1+\frac{\psi}{\epsilon}\right)\right]}{\cos\left[\frac{\pi}{2}\left(1+\frac{\psi}{\epsilon}\right)\right] - K \cos\left[\frac{\pi}{2}\left(1-\frac{\psi}{\epsilon}\right)\right]} = \frac{\epsilon}{\pi} \tan^{-1} \frac{1-K}{1+K} \cot \frac{\pi}{2}\frac{\psi}{\epsilon}$$

The above equation divided by ϵ is plotted in Figur as a function of various $\frac{\psi}{\epsilon}$ ratios. Multiplying i factor obtained from the curve, by ϵ, results in the bo sight shift in degrees. It can be seen that the grea values of the ratio $\frac{\psi}{\epsilon}$, the smaller the boresight sh will be for a given voltage unbalance. However, any particular ratio $\frac{\psi}{\epsilon}$ and voltage unbalance smaller boresight shift will result when using the n rowest beamwidth.

If the sine function assumed to describe the ante lobes is not a reasonable approximation of the act antenna patterns, the amount of null shift as a funct of voltage unbalance can still be computed from slopes of the two antenna patterns around the crosso

Figure 10a shows the antenna patterns with and wi out a voltage unbalance. Lobe B_1 indicates the eq voltage balance condition and Lobe B_2 the unbalan condition. Since the boresight point is at the intersect of Lobe A and Lobe B, it can be seen that the angle which the intersection occurs is shifted by an angle, in changing from Lobe B_1 to B_2. Let us assume that

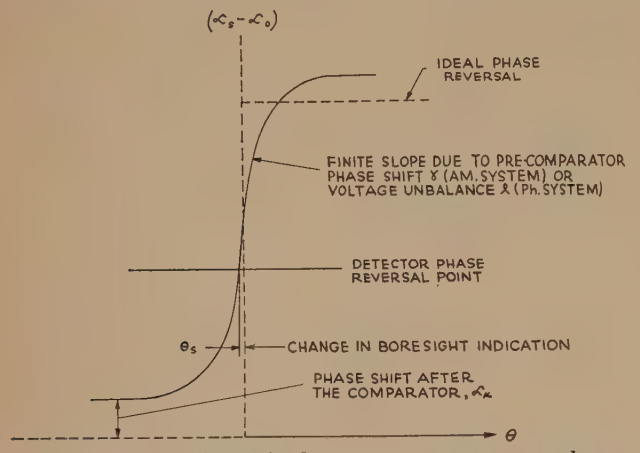

$(\alpha_s - \alpha_o)$
IDEAL PHASE REVERSAL
FINITE SLOPE DUE TO PRE-COMPARATOR PHASE SHIFT & (AM. SYSTEM) OR VOLTAGE UNBALANCE & (Ph. SYSTEM)
DETECTOR PHASE REVERSAL POINT
θ_s
CHANGE IN BORESIGHT INDICATION
PHASE SHIFT AFTER THE COMPARATOR, α_x
θ

Figure 8 — Boresight shift due to pre-comparator and post-comparator phase shifts. (Amplitude-sensing monopulse).

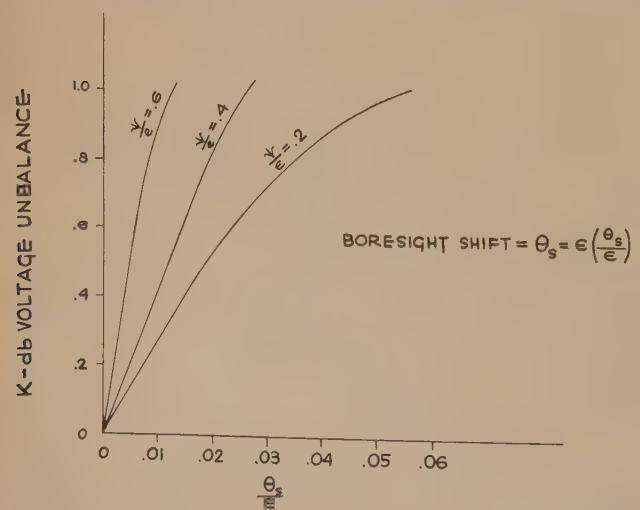


Figure 9 — Boresight shift vs. pre-comparator voltage unbalance for an amplitude-sensing monopulse system.

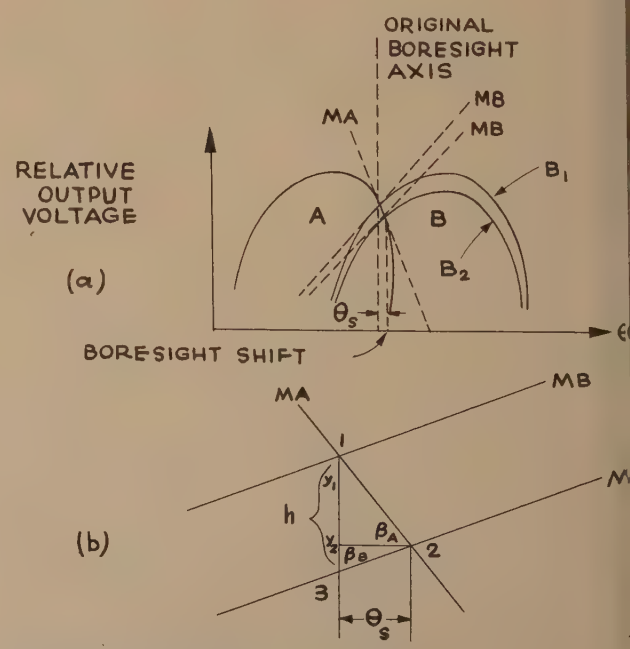


Figure 10 — Boresight shift in amplitude-sensing monopu

lope of Lobe A is constant near the intersection of the wo lobes and equal to M_A. This is generally true for mall losses in the reception of Lobe B. Let the slope of obe B $= M_B$ around the intersection point. Let h = he loss in channel B and θ_S = the shift of the bore-ight indication due to this loss. Referring to Figure 0b, a vertical line (h) is drawn from points 1 to 3 nd the line θ_S drawn perpendicular to h and passing hrough point 2.

We can deduce by trigonometry that

$$\tan \beta_A = M_A \text{ and } \tan \beta_B = M_B$$

rom the diagram one can see that

$$\tan \beta_A = \frac{y_1}{\theta_S} \qquad \tan \beta_B = \frac{y_2}{\theta_S}$$

nd $y_1 = h - y_2$

ubstituting $|M_A| = \frac{y_1}{\theta_S}$ and $|M_B| = \frac{y_2}{\theta_S}$

nd solving for θ_S

$$\theta_S = \frac{y_2}{|M_B|} = \frac{y_1}{|M_A|}$$

ubstituting

$$\frac{|M_B|}{|M_A|}(h - y_2) = y_2$$

nd transposing

$$\frac{|M_B|h}{|M_A|} = y_2 + \frac{|M_B|y_2}{|M_A|}$$

herefore

$$y_2 = \frac{|M_B|h}{|M_A|\left(1 + \frac{|M_B|}{|M_A|}\right)} = \frac{|M_B|h}{|M_A| + |M_B|}$$

o

$$\theta_S = \frac{h}{|M_A| + |M_B|} \qquad (9)$$

Since it is desirable to keep θ_S as small as possible nd assuming h is a given quantity, it then becomes bvious that M_A and M_B, the slopes, must be as large as ossible. For example, if the actual antenna patterns were of the general shape as shown in Figure 4, it would e best to have the beamwidth, ϵ, as narrow as possible nd the beam separation, ψ, as large as possible. Of ourse, as was mentioned before, there are many other arameters which would actually limit the values of and ψ.

END PART I

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List of Symbols

a_1, a_2, a_3 Coefficients in Taylor Series
d Distance between Feedhorn Centers
E_D Difference I.F. Signal Voltage
E_S Sum I.F. Signal Voltage
E_D Signal Voltage in Difference Channel
E_{D2} Signal Voltage in Difference Channel with Voltage Unbalance
E_S Signal Voltage in Sum Channel
E_{S1} Signal Voltage in Sum Channel with Phase Shift
E_{S2} Signal Voltage in Sum Channel with Voltage Unbalance
E_o Output Voltage from Phase Detector
f Focal Length of Paraboloid Antenna
h Loss in Channel B
i_c Mixer Crystal Current
K Ratio of Signal Voltage Loss in Channel B to Channel A
K_1 Received Signal Level in a Single Feedhorn
K_D Amplitude of Difference Signal
K_{D1} Amplitude of Difference Signal with Phase Shift
K_{D2} Amplitude of Difference Signal with Voltage Unbalance
K_S Amplitude of Sum Signal
K_{S1} Amplitude of Sum Signal with Phase Shift
K_{S2} Amplitude of Sum Signal with Voltage Unbalance
K_{OD} Amplitude of Local Oscillator Signal at Difference Mixer
K_{OS} Amplitude of Local Oscillator Signal at Sum Mixer
l Ratio of Signal Voltage in Channel B to that in Channel A
K_p Parabolic Antenna Constant (.6)
M_A Slope of Lobe A Near the Boresight Axis
M_B Slope of Lobe B Near the Boresight Axis
n Distance between Phase Center of Closely Spaced Feedhorns
S Extra Path Delay in Antenna B
α_D Phase Angle of Difference Signal Voltage
α_{D1} Phase Angle of Difference Signal Voltage with Phase Delay γ
α_{D2} Phase Angle of Difference Signal Voltage with Voltage Unbalance
α_K Phase Shift Between Sum and Difference Channel (After the Comparator)
α_S Phase Angle of Sum Signal Voltage
α_{S1} Phase Angle of Sum Signal Voltage with Phase Delay γ
α_{S2} Phase Angle of Sum Signal Voltage with Voltage Unbalance l
α_{OD} Phase Angle of Local Oscillator Voltage at Difference Mixer
α_{OS} Phase Angle of Local Oscillator Voltage at Sum Mixer
γ Spurious Phase Shift
ϵ Beamwidth of Each Lobe
θ Angle of Return Signal Wavefront with Respect to the Plane of the Antenna Apertures (See Figures 1 & 2)
θ_{NA} Angle at which the First Null of Lobe A Occurs $0° > \theta > -90°$
θ_{NB} Angle at which the First Null of Lobe B Occurs $0° > \theta > -90°$
θ_S Boresight Shift
λ Wavelength of Carrier
π 3.14
ϕ Phase Delay Due to Distance S
ψ Separation Between Lobes
ω_c 2π Carrier Frequency
ω_o 2π Local Oscillator Frequency

A NEW RECEIVER for ANTENNA PATTERN RANGES

A video type system for use in making antenna pattern measurements is described. The treatment is centered around the receiver which operates at 1,000 cycles per second. A complete system is described briefly and the various important parameters are discussed. Using the receiver described with the required associated equipment, antenna patterns can be measured with a dynamic range in excess of 40 db with an accuracy of .1 db per 10 db. This is made possible by the very narrow receiver bandwidth which is adjustable between 2 and 15 cycles per second. Considering a 40 db transmission loss between antennas, a source power of only 10 milliwatts is required. The receiver is also suitable for making other types of insertion loss measurements and can be used with either crystal diode detectors or barretters. The crystal diode is preferred when making antenna pattern measurments because of its high sensitivity and the consequent low r.f. power required, while the barretter is preferred for insertion loss measurements up to 50 db because of its stability and linearity.

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Introduction

The problem of an antenna pattern measurement is, basically, one of measuring relative power density, as a function of angle, either elevation or azimuthal, due to radiation from the antenna under test. This can be accomplished in several different ways, one of which is described here.

Figure 1 shows a block diagram of the major components of a pattern measurement setup. The antenna under test can be either the transmitting or receiving antenna, but convenience usually dictates that it be placed in the receiving position.

The transmitter must supply the required power at the proper frequency so that, considering the path loss between antennas, the proper power level is available at the receiver. This obviously depends on many factors such as antenna gain and separation between antennas. The receiver must deliver an output to the recorder that is some known function of the radio frequency power received. This is usually either a linear or a square-law function. In the first, the receiver voltage output is directly proportional to the r.f. input voltage, while in the square-law case the receiver voltage output is proportional to the r.f. power input.

The recorder makes a permanent record of received power vs. antenna position. Where a wide dynamic range must be covered, a recorder with a logarithmic characteristic is a necessity. The pattern is then plotted on a decibel scale. It should be noted that the decibel scales employed depend on whether a linear or square-law detector is used and that they differ by a factor of two.

In writing the specifications for system to make a given measuremen the engineer should take a critical loo at his requirements. In making a antenna pattern measurement, sever of the more important parameters t be considered are: (1) the dynam range or the power ratios to be co ered; (2) the accuracy or linearity r quired; and (3) the ease and conven ence of the measurement. In the and D laboratory where the antenn pattern may be only one of mar measurements to be made, flexibili of the equipment is very often a fa

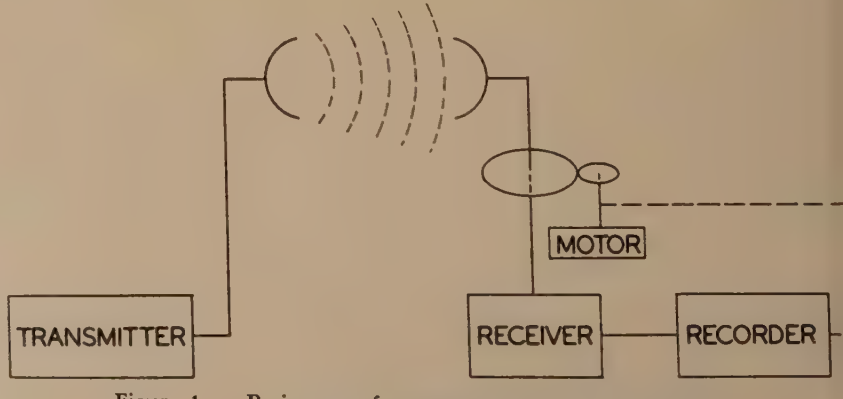


Figure 1 — Basic setup for antenna pattern measurements.

or as it is when it is necessary to over a wide range of frequencies.

The three parameters given above re not in general compatible. For xample, if one is willing to sacrifice ccuracy, the dynamic range can be ncreased; or the measurement can be ade more rapidly if a wide band sys-m is used, but linearity at low sig-al level suffers. This points out the ecessity for meaningful specifications nd an accurate appraisal of the re-uirements.

The above parameters will be tiefly discussed before going on to ne actual equipment, since it is felt nat a better understanding of the pecifications will result.

First, let us consider the dynamic nge or the power ratios to be cov-ed. This is usually determined by ne importance attached to the detec-on and measurement of side lobes f the antenna pattern. If good lin-arity can be maintained over a range f 40 decibels, this is usually suffi-ient, although some special applica-ons require a wider range. It should lso be borne in mind that a smaller nge might suffice, in which case cer-in other advantages can sometimes e realized.

The dynamic range is limited on ne high end by the overload charac-eristics of the amplifier used or de-arture from a square law or linear haracteristic of the detector. The low nd is determined by the system noise hrough two quite different effects. irst, the noise causes a fluctuation of ne output indicator or recorder around s true reading, making it difficult o determine the true indication. Sec-ndly, it causes an increase in the verage indicator reading when an verage detector is used. The first ffect can be counteracted by the use f indicators having long time con-tants. In theory, at least, this can be arried to any extreme to render a sable reading. Practically, however, here is no need going past the point vhere the second effect becomes im-ortant. Another undesired effect of long indicator time constant is the dded length of time required for a neasurement. The second effect can e counteracted only by maintaining good signal to noise ratio at the utput detector. One way of accom-lishing this is to restrict the band-vidth of the amplifier preceding the etector. A narrow bandwidth, how-ver, has the same effect as a long in-dicator time constant, i.e., it increases the time required to make a measurement. Decreasing the bandwidth preceding the detector does not reduce the indicator fluctuation; this can only be done by increasing the indicator time constant.

The second parameter to be discussed, the accuracy or linearity required, depends on many things. Where a recorder is used as an output indicator, the precision to which it can be read is very often a limiting factor. Even if a high degree of linearity is not required when making antenna measurements, it should be borne in mind that this same equipment can be used in making insertion loss measurements of other types, since both are measurements of power ratios. In the interest of flexibility, therefore, a high degree of linearity is considered desirable.

Ease and convenience of measurements are rather difficult to consider generally, since they depend on factors not always under the engineer's control. Where a large number of measurements are to be made, these factors become important and automatic systems become economically feasible. As indicated above, the dynamic range and accuracy requirements limit the speed with which a measurement can be made in that the system bandwidth is a factor in determining the system noise. If only an occasional pattern is to be measured, it can be done by taking point by point readings and plotting the data manually. This can be very tedious, however, and one runs the risk of missing some of the fine structure of the pattern.

There are a number of precautions that must be taken in setting up the antennas for measurement. Since the purpose of this paper is to describe only one segment of the required instrumentation, and since setup procedures have been covered in some detail in the literature (Ref. 1), there will be no attempt to do so here.

We will concern ourselves in the remainder of this paper with a receiving system that has been designed with the above described application in mind. Most instrumentation for this purpose has used either a superheterodyne or a video type receiver. A superheterodyne receiver has the advantage of a somewhat higher sensitivity and wider dynamic range. It results in a linear system, i.e., one in which the receiver output voltage is proportional to received voltage. The video receiver, on the other hand, can claim the advantages of simplicity, economy (a local oscillator is not required) with a dynamic range and linearity well beyond what has been credited to it in the past. Both types of receivers have been recommended for this application (Ref. 1).

The receiver described in this paper is of the video type with a center frequency of 1 kc/s, an adjustable bandwidth, provisions for driving a recorder, a built-in indicator and other features to be described. It is the Weinschel Engineering Model BA-7. It requires an r.f. source of the proper frequency modulated at a frequency of 1 kc/s and the other instrumentation normally associated with an antenna pattern range. The purpose of this paper is to describe the receiver and outline its specifications in relationship to the requirements of the measurement and to the required associated equipment.

The Video Receiver

Since the BA-7 was designed with the application of antenna pattern measurements in mind, it will be discussed in connection with such a setup. The characteristics of the required associated instrumentation will also be considered where appropriate.

Figure 2 shows a block diagram of the instrumentation in sufficient detail to allow proper discussion.

The antenna under test is mounted on a turntable in the receiving position. The receiver has been broken down into its major components: a tuner, a detector and a narrow band receiver (the BA-7) tuned to 1000 cycles per second. The output is fed to a recorder and to an output indicator which, in this case, is mounted on the receiver front panel. The recorder is caused to move in one coordinate in synchronism with the antenna rotation thereby producing a plot of signal vs. angle of rotation (See Figures 11 and 12). The transmitter must supply a modulated signal of sufficient power at the correct frequency to establish the proper level at the receiver. More will be said of each of these components as they are considered in their relationship to the receiver.

A block diagram of the BA-7 is shown in Figure 3 and a photograph of the receiver front panel is shown

in Figure 4. Let us first briefly consider the components as shown in Figure 3. The r.f. signal is detected in either a silicon crystal or a biased barretter. The BA-7 includes a barretter biasing circuit and a front panel meter to aid in adjustment. The biasing current is well filtered to prevent addition of noise to the signal at this point. There are many engineers who can attest to the fact that barretters are quite subject to burnout due to surge currents from condenser discharges when connecting them to the bias supply. It was felt, therefore, that a barretter biasing circuit with the necessary safeguards built in would be worthwhile. As a result, it is possible to connect and disconnect the barretter at will without danger of burnout due to current surges. When a crystal is used, the barretter biasing circuit is inoperative. The choice between crystal and barretter must be made on the basis of required dynamic range, available power and required linearity and is covered in detail later in the paper.

A selective preamplifier follows the detector. It is designed for the lowest possible noise level to provide for the maximum dynamic range. A large amount of negative feedback is employed to insure satisfactory linearity.

As was pointed out above, a narrow bandwidth has the advantage of reducing the noise, but the required observation time is increased, thereby reducing the allowable recording speed. The tuned amplifier and bandwidth control provide the engineer with any bandwidth between 2 and 15 cycles per second centered at 1 kc/s with a negligible dependence of gain on bandwidth. The engineer thus has the choice of bandwidth that best suits his needs.

The recorder amplifier provides three output impedances to provide for operation with any recorder. A vacuum tube voltmeter indicates output voltage allowing patterns to be taken point by point or to allow the instrument to be used in making other types of insertion loss measurements.

Before considering the details of the BA-7, let us look at the specifications in relation to the entire system. We shall first consider the system dynamic range. Much of the information presented in the following is taken from Reference 3. Two types of square law detectors, crystal diodes and barretters are used in this application. It is neces-

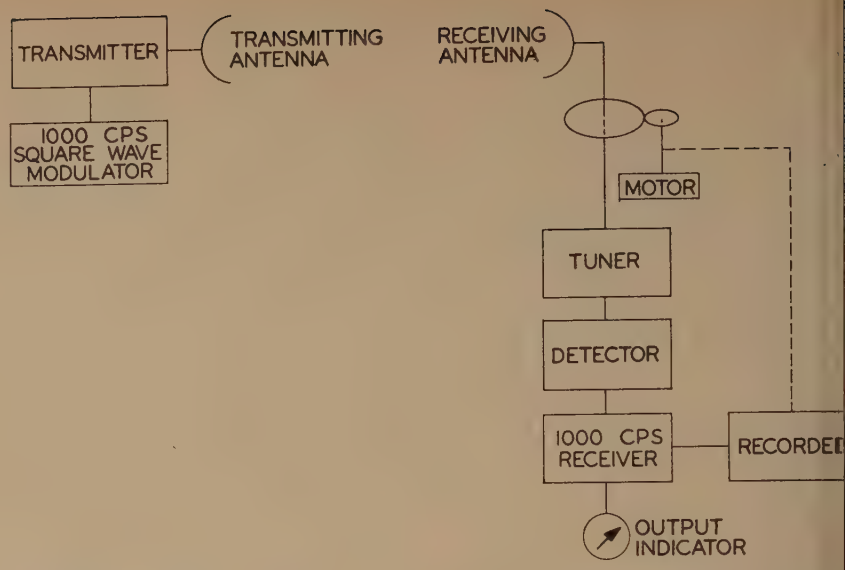


Figure 2 — Setup for antenna pattern measurements using the Model BA-7.

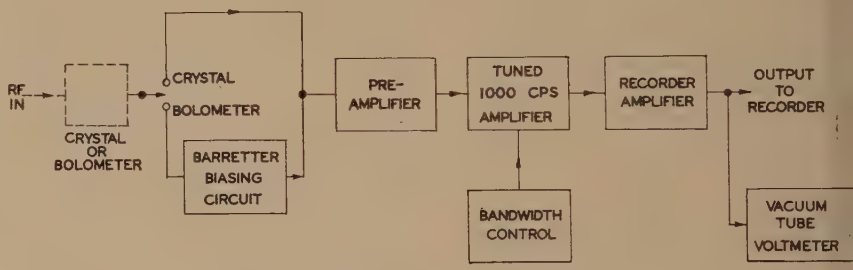


Figure 3 — Block diagram of the BA-7.

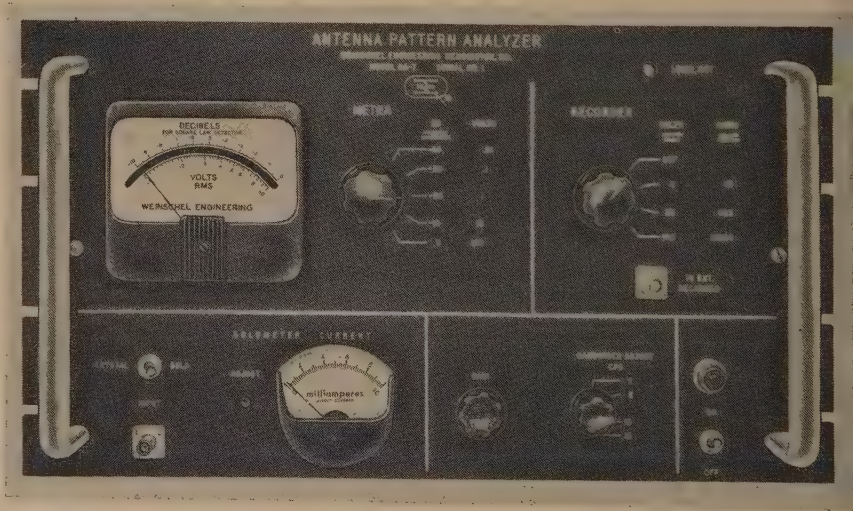


Figure 4 — Front panel view of BA-7.

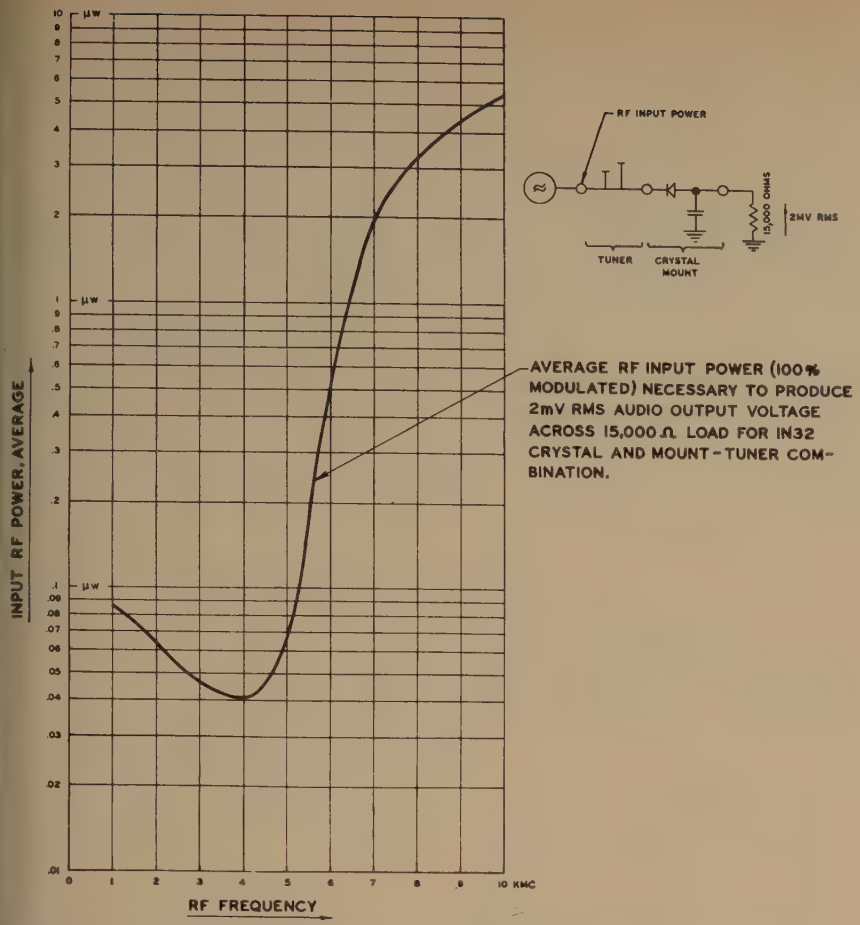
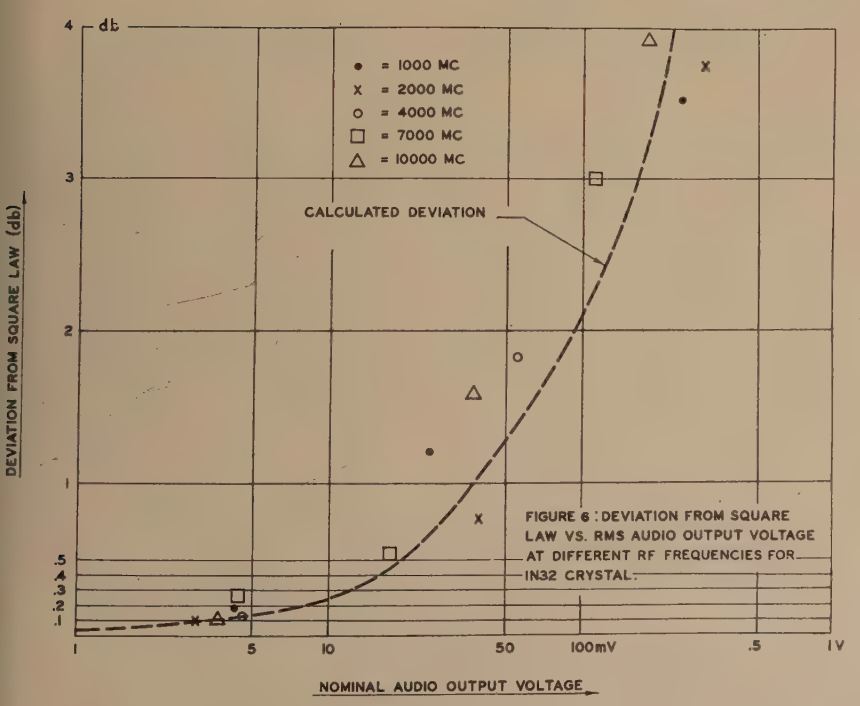

INPUT RF POWER, AVERAGE
RF FREQUENCY
10 KMC
RF INPUT POWER
2MV RMS
15,000 OHMS
TUNER
CRYSTAL MOUNT
AVERAGE RF INPUT POWER (100% MODULATED) NECESSARY TO PRODUCE 2mV RMS AUDIO OUTPUT VOLTAGE ACROSS 15,000Ω LOAD FOR IN32 CRYSTAL AND MOUNT-TUNER COMBINATION.

Figure 5 — RF power vs frequency to produce constant audio output voltage.



igure 6 — Deviation from square law vs. RMS audio output voltage at different RF frequencies for IN32 crystal.

sary to discuss them along with the receiver since the noise contributed by the detector is important in determining the minimum signal that can be received and the departure from a square law characteristic determines the maximum signal level.

The noise resistance of a video crystal is about 15,000 ohms (Ref. 3). The noise resistance of a barretter, on the other hand, is equal to its d.c. resistance, which in this case is close to 200 ohms, but since it is operated at an elevated temperature due to the d.c. bias current, this corresponds to an equivalent noise resistance of approximately 300 ohms at room temperature. With this information and the equivalent noise of the receiver, to be given later, it is possible to determine the minimum usable receiver input signal level. The radio frequency input power required to produce this signal depends, of course, on the detector sensitivity.

The other detector characteristic of importance at this time is the overload characteristic. Neither crystal diodes nor barretters maintain their square law characteristic for large input signals and it is important to know the limits of operation for a given error. Figures 5, 6 and 7 show the important characteristics for both crystal diodes and barretters. The derivation of this as well as additional valuable information is given in Reference 3.

As mentioned earlier, the presence of noise in the system has two undesired effects: (1) it causes a fluctuation of the output indicator; and (2) it causes an increase in the average output. Both of these effects are analyzed in detail in References 4, 5 and 6 and are shown in Figures 8 and 9. The increase in the average reading shown in Figure 8 is the more serious of the two effects since it results in an error that is not apparent to the observer while it is possible to average out the fluctuations by an increased observation time. This is particularly easily done when a recorder is used on the output.

If the error due to the effect shown in Figure 8 is to be kept less than 0.1 db, the signal-to-noise ratio should not drop below about 4:1 as can be seen from Figure 8. Reference to Figure 9 shows that this signal-to-noise ratio produces an rms fluctuation of approximately 27% at the output.

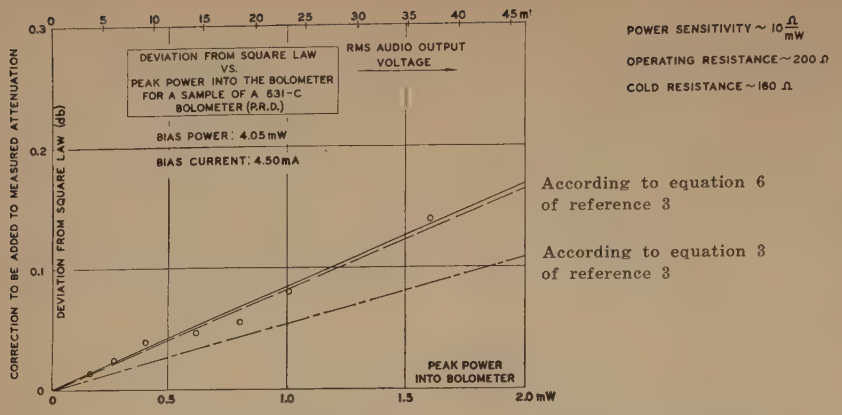

DEVIATION FROM SQUARE LAW VS. PEAK POWER INTO THE BOLOMETER FOR A SAMPLE OF A 631-C BOLOMETER (P.R.D.)
RMS AUDIO OUTPUT VOLTAGE
POWER SENSITIVITY ~ 10 Ω/mW
OPERATING RESISTANCE ~ 200 Ω
COLD RESISTANCE ~ 160 Ω
BIAS POWER: 4.05 mW
BIAS CURRENT: 4.50 mA
CORRECTION TO BE ADDED TO MEASURED ATTENUATION
DEVIATION FROM SQUARE LAW (db)
According to equation 6 of reference 3
According to equation 3 of reference 3
PEAK POWER INTO BOLOMETER
0 5 10 15 20 25 30 35 40 45 mW
0.3 0.2 0.1 0
0 0.5 1.0 1.5 2.0 mW

Figure 7 — Deviation from square law vs. peak power for PRD 631-C bolometer.

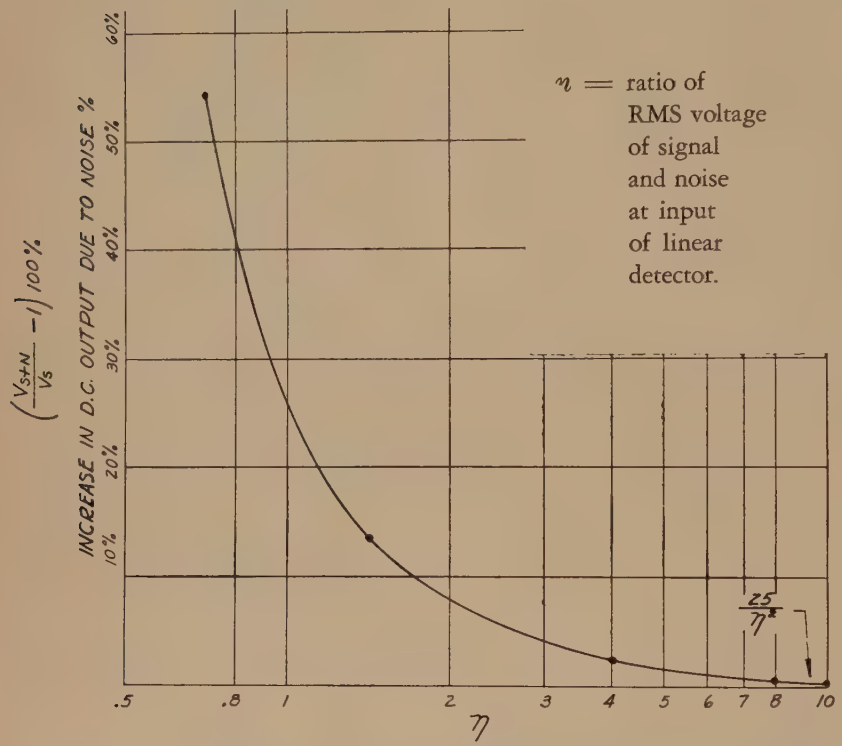

η = ratio of RMS voltage of signal and noise at input of linear detector.
$\left(\frac{V_{S+N}}{V_S} - 1\right) 100\%$
INCREASE IN D.C. OUTPUT DUE TO NOISE %
60% 50% 40% 30% 20% 10%
$\frac{25}{\eta^2}$
.5 .8 1 2 3 4 5 6 7 8 10
η

Figure 8 — Linear detector, increase of average output due to noise.

Figure 9 assumes that

$$Bt > 1$$

where: B = receiver bandwidth and
t = indicator time constant.

This amount of fluctuation is considered to be excessive and to reduce it to a maximum of 20% requires an increase in the minimum signal-to-noise ratio to 8:1. This ratio will be used for subsequent discussion.

We next determine the equivalent noise referred to the receiver input. A noise resistance of 1200 ohms satisfactorily represents the receiver noise. It is also necessary to consider the noise contributed by the detector. At this point, it is advantageous to consider the two types of available detectors, crystals and barretters, separately. Assuming a noise resistance of 15,000 ohms for the crystal and a receiver bandwidth of 5 cycles per second, we calculate an equivalent noise input voltage of

$$e_{nc} = \sqrt{4KTRB}$$
$$= \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 16200 \times 5}$$
$$= 37 \times 10^{-9} \text{ VOLTS}$$

The minimum audio input voltage to maintain the desired 8:1 signal-to-noise ratio is therefore:

8 x 37 = 296 millimicrovolts.

Reducing the bandwidth to 2 cycles per second multiplies these voltages by $\sqrt{2/5}$ for a minimum input signal of 187 millimicrovolts. Following a similar procedure for the barretter we obtain minimum input signals of 110 and 70 millimicrovolts for bandwidths of 5 and 2 cycles per second respectively.

To determine the dynamic range it is now necessary to find the maximum levels that can be handled by the detector-receiver combination without excessive departure from linearity. Reference to Figure 6 and Reference 3 shows that an audio output of 1 millivolts can be obtained from the crystal within the requirement that the departure from square law introduces less than 0.1 db error in the measurement. The receiver can handle this signal without overload and we find the linear range of

$$\frac{2 \times 10^{-3}}{.296 \times 10^{-6}} = 6750$$

or a range of 38.3 db for a bandwidth of 5 cycles per second and

$$\frac{2 \times 10^{-3}}{.187 \times 10^{-6}} = 10{,}700$$

or a range of 40.3 db for a bandwidth of 2 cycles per second. It should be noted that a 10:1 voltage ratio is interpreted as a 10 db dynamic range. The dynamic range is in terms of power levels at the input to a square law detector and the fact that a 10 db power change at this point results in a 10:1 voltage change at the detector output accounts for this apparent discrepancy.

As shown in Figure 5, the r.f. required to produce the required 2 millivolts at the receiver is quite dependent on frequency. At frequencies up to about 6500 megacycles, one microwatt at the crystal is sufficient. If we assume a 40 db loss between antennas an average power of 10 milliwatts will be required at the transmitting antenna. At frequencies above 6500 megacycles, a higher power is indicated by Figure 5 will be required. Figure 5 is typical for crystal diodes in coaxial line mounts. The same diodes in waveguide mounts at the higher frequencies give somewhat better performance. There is also some variation in the characteristic from crystal to crystal.

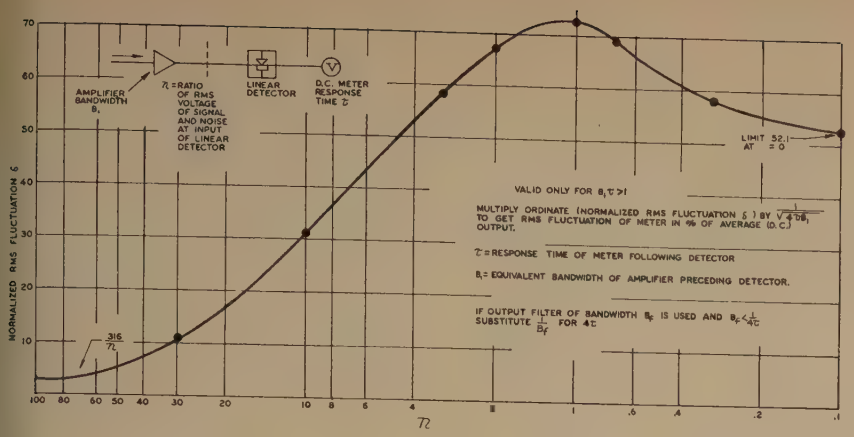

NORMALIZED RMS FLUCTUATION δ
AMPLIFIER BANDWIDTH B_i
γ = RATIO OF RMS VOLTAGE OF SIGNAL AND NOISE AT INPUT OF LINEAR DETECTOR
LINEAR DETECTOR
D.C. METER RESPONSE TIME τ
LIMIT 52.1 AT $\gamma = 0$
VALID ONLY FOR $B_i\tau > 1$
MULTIPLY ORDINATE (NORMALIZED RMS FLUCTUATION δ) BY $\sqrt{4\tau B_i}$ TO GET RMS FLUCTUATION OF METER IN % OF AVERAGE (D.C.) OUTPUT.
τ = RESPONSE TIME OF METER FOLLOWING DETECTOR
B_i = EQUIVALENT BANDWIDTH OF AMPLIFIER PRECEDING DETECTOR.
IF OUTPUT FILTER OF BANDWIDTH B_f IS USED AND $B_f < \frac{1}{4\tau}$ SUBSTITUTE $\frac{1}{B_f}$ FOR 4τ
$\frac{.316}{\gamma_1}$
γ

Figure 9 — Output fluctuation vs. signal-to-noise ratio at input to average detector.

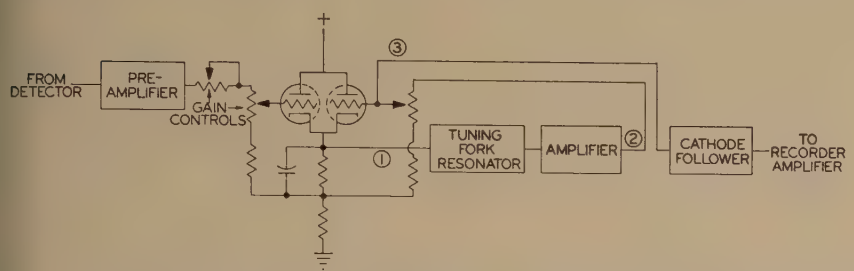


Figure 10 — Block diagram showing arrangement of narrow band amplifier and bandwidth control.

A similar treatment for the barretter shows the following: As shown in Figure 7, an audio output voltage of .5 millivolts can be obtained within the limit of a 0.1 db error due to departure from square law. A treatment similar to that used with the crystal yields dynamic ranges of 53.6 db and 45.5 db for bandwidths of 5 and 2 cycles per second respectively. The input voltage to the receiver should not exceed 7 millivolts and so to realize this dynamic range would require an audio attenuator between the barretter and receiver to prevent overload at the high levels. Without such an attenuator, the dynamic range becomes 48 db and 50 db for bandwidths of 5 and 2 cycles per second respectively. Thus, it can be seen that the barretter provides the greatest dynamic range. The disadvantage of the barretter becomes apparent when the required r.f. power is calculated. Again, let us assume a path loss of 40 db between antennas. Reference to Figure 7 shows that an r.f. power level of 300 microwatts is required at the barretter to produce an audio voltage of 7 millivolts for the receiver. Considering the transmission loss, a power level of 3 watts would be required at the transmitting antenna. The important results are summarized in Table 1.

It should be pointed out that when this equipment is used to make insertion loss measurements, the full dynamic range of the barretter can be realized since the upper level can be adjusted by means of attenuators. For a more detailed consideration of the relative merits of these two types of detectors, the reader is referred to Reference 3. The dynamic ranges given above for crystal diode operation are calculated on the basis of a maximum error of 0.1 db at the low end due to output indicator fluctuation and of 0.1 db at the high end due to departure from a square law characteristic of the crystal. If the detector-receiver combination is considered, the dynamic range at a 2 cycle per second bandwidth, assuming a required linearity of .1 db/10 db, is 45 db. An observation time of about 45 seconds is required. In the event a wider dynamic range is necessary to see the fine structure in the minor lobes of the pattern, this is possible by the simple expedient of allowing the system to be overdriven on the main lobe while looking at the minor lobes and then recording a second pattern with reduced power to look at the main lobe. Figures 11a and 11b show an example of this technique.

Detector	Dynamic Range B = 2 cps	Dynamic Range B = 5 cps	Average Power Required At Detector
1N32 Xtal	40 db	38 db	1 Microwatt
Barretter	50 db	48 db	300 Microwatts

Table I

The input impedance to the receiver is not less than 15,000 ohms resistive. It was found that this provided a suitable compromise between crystal detector loading and noise to produce the maximum dynamic range. This impedance is high enough to produce negligible loading of a barretter. Transformer coupling to the input stage is used to achieve the lowest possible noise. As stated above, the equivalent noise resistance of the receiver is 1200 ohms maximum.

A large amount of negative feedback is used around the preamplifier to insure a high degree of linearity independent of tube characteristics and aging.

The output of the preamplifier is taken from a cathode follower and applied to the tuned amplifier through a coarse and fine gain control. The coarse gain control has a range of about 3:1, while the fine control has a range of approximately 10%. The total range of gain adjustment covers a range of approximately 5 db at the input to the square law detector (r.f.). The tuned 1 kc/s amplifier and the bandwidth control perform the function of restricting the bandwidth and at the same time bringing it under control of the operator who can choose any bandwidth between 2 and 15 cycles per second without having to readjust gain.

Figure 10 shows a block diagram of the unit from which we can discuss its mode of operation. The input to the unit is made through a cathode coupled mixer serving the purpose of injecting the feedback voltage into the system and providing a low impedance source from which to drive the tuning fork resonator. This resonator has a working Q of about 10,000 which would yield a bandwidth of 0.1

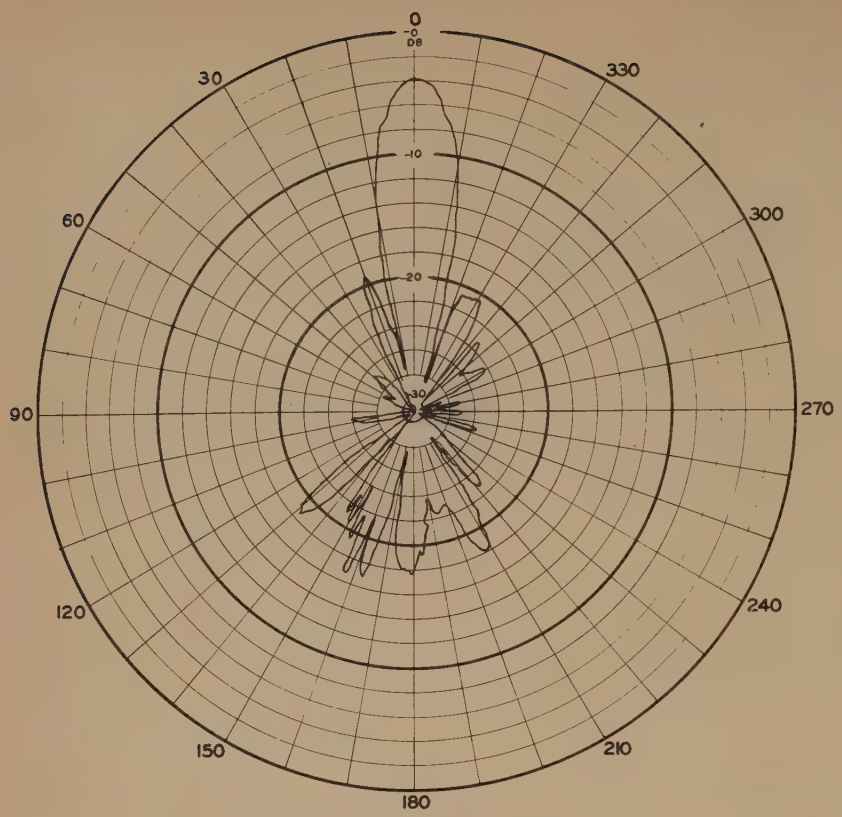


Figure 11a — Entire pattern.

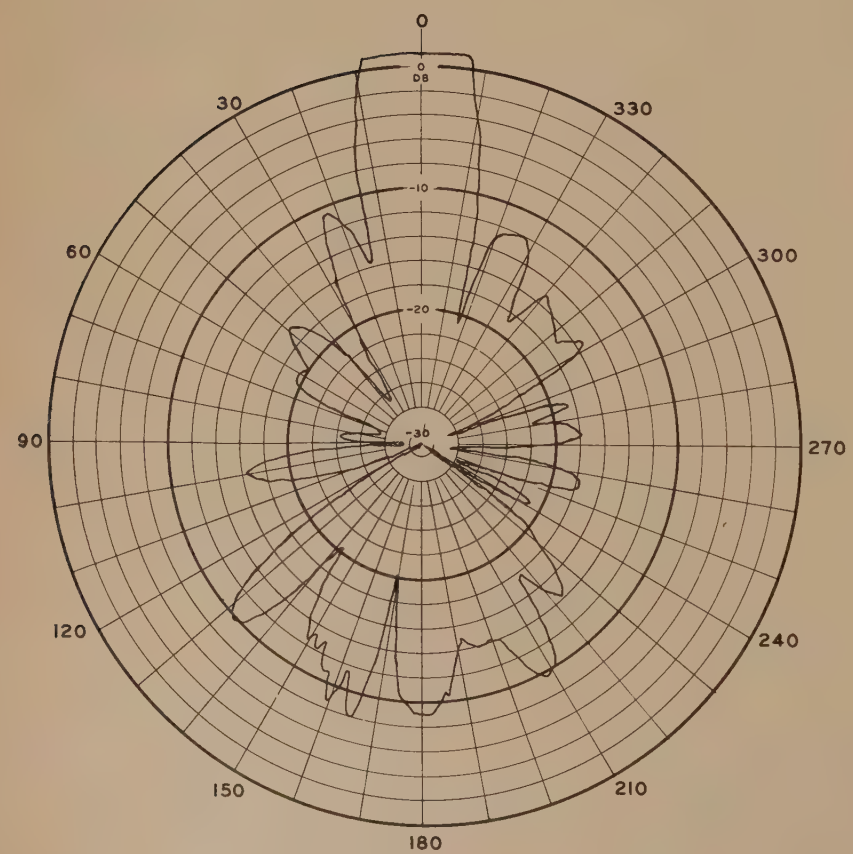


Figure 11b — Expanded recording of minor lobes.

Figure 11 — Typical antenna pattern recording in polar coordinates on a logarithmic scale.

cycles at a center frequency of 1 kc
The application of negative feedba
around the resonator has the effect
increasing the bandwidth and impr
ing the linearity of the tuning fc
when used as a band filter. The fe
back is made variable to provide
variable bandwidth with the mi
mum amount of feedback adjusted
provide a bandwidth of 2 cycles
second and the maximum feedba
adjusted to provide a bandwidth
15 cycles per second.

The usual arrangement provi
feedback between output and input
the amplifier, the effects of which ha
been treated at great length in ma
standard electronic engineering te
The effect of negative feedback
bandwidth has been well covered
these texts and no additional cover
is required here. The arrangem
shown in Figure 10, however, diff
from the usual in that the output
taken from a point where the volt
is proportional to the amount of fe
back. Since, if the feedback is lar
the gain is inversely proportional
feedback, the output voltage can
held constant and the circuit theref
exhibits a constant gain while
bandwidth can be varied. Three poi
on Figure 10 are labeled as 1, 2 a
3 respectively. The gain from 1 t
is given by

$$A_{12} = \frac{A}{1 + A\beta}$$

where: A = gain from 1 to 2 witho
feedback

β = fraction of signal
back from 2 to 1

$$= K\frac{E_3}{E_2}$$

A_{12} = gain from 1 to 2 w
feedback.

The output is taken from Point 3
that

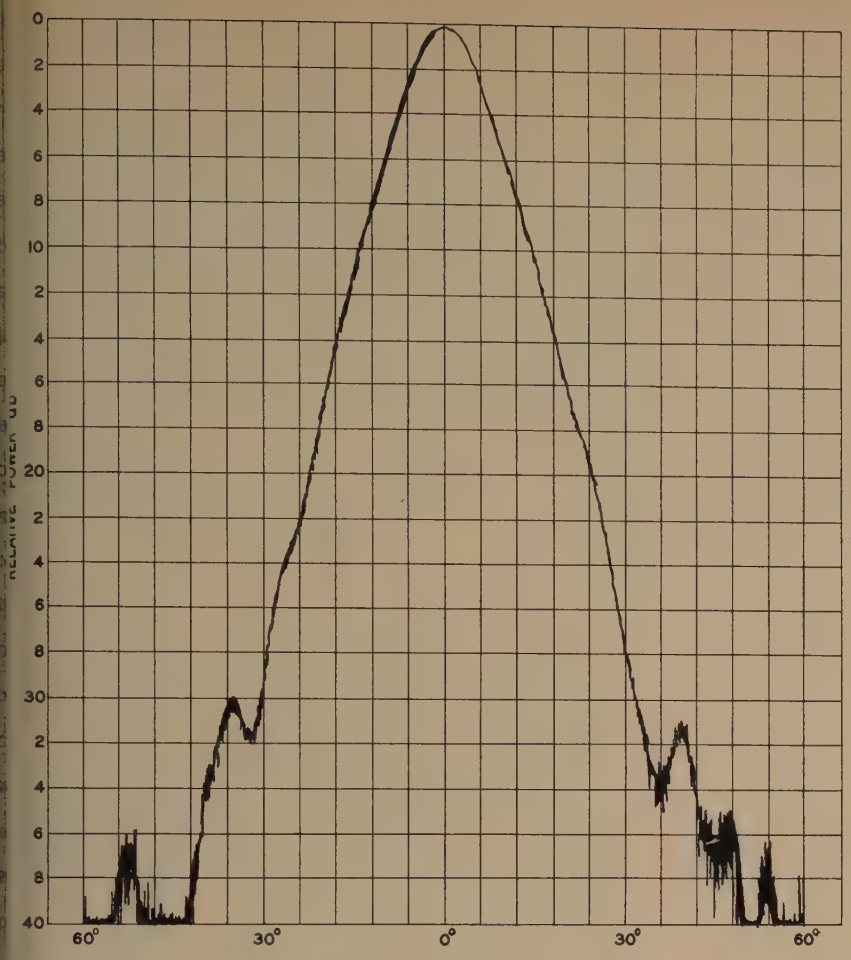
$$A_{13} = \frac{A}{1 + A\beta} \cdot \frac{E_3}{E_2} = \frac{A}{1 + A\beta} \cdot$$

If $A\beta$ is large compared to 1

$$A_{13} = \frac{1}{\beta} \cdot \frac{\beta}{K} = \frac{1}{K}$$

and we see that the gain betwe
Points 1 and 3 is substantially ind
pendent of feedback. In practice,
was possible to guarantee that the g
would vary no more than 10%
variations in bandwidth between 2 a
15 cycles per second and by no m
than 5% for bandwidths between
and 15 cycles per second.

The very narrow bandwidth ca
bilities of the BA-7 require that
transmitters used be modulated fr
a source having exceptionally g



gure 12 — Typical antenna pattern recording in rectilinear coordinates on a logarithmic scale.

quency stability. This practically quires that the modulating signal be rived from an oscillator that is tun- g fork controlled. Because of this, has been necessary to develop an tire line of r.f. power sources with ompanion modulator fulfilling these quirements.

The narrow band tuned amplifier eds the recorder amplifier where the gnal is further amplified and fed the external recorder jack on the ceiver front panel. A tapped output nsformer is used to provide a choice three output impedances. The unit ll deliver the following open circuit ltages and can be loaded with the dicated impedances without deteri- ation of the output waveform:

ıp #1	100 volts rms	10,000 ohms
ıp #2	25 volts rms	625 ohms
ıp #3	6 volts rms	45 ohms

n OFF position is also provided on e output switch so that the recorder gnal can be disconnected without dis- ling the rest of the circuit or with- it disconnecting the built-in output cuum tube voltmeter. A LEVEL T control is available by means of screwdriver adjustment from the front panel to allow adjustment of the recorder signal for the proper recorder deflection without having to readjust the gain control. This control is out of the circuit when the output switch is in the OFF position. This allows the operator to adjust the gain control by watching the output indicator with no danger of overdriving the narrow band amplifier. If it were not for this arrangement, the operator could increase the gain to obtain the proper recorder deflection while the LEVEL SET was in a position that substantially decreased the gain of the recorder amplifier. Under such conditions, it would be possible to overdrive the narrow band amplifier without obtaining an excessive output indication.

The recorder amplifier is provided with a large amount of negative feedback to insure its linearity and stability. The feedback is taken from the secondary of the output transformer to include it in the feedback loop since it could account for most of the nonlinearity in such an amplifier.

A conventional vacuum tube voltmeter is permanently connected to the highest voltage tap of the output transformer and continuously indicates the output voltage. The meter has an overall accuracy of 2% and is equipped with both voltage and decibel scales. It covers a voltage range of from .01 to 100 volts in decade ranges. The decibel scale is calibrated in terms of the r.f. power into a square law detector. A decade voltage range, therefore, corresponds to only 10 decibels.

Conclusion

The receiver described, the Weinschel Engineering Model BA-7, is a video receiver operating at 1 kc/s. Its major features include excellent linearity over a very wide dynamic range, variable bandwidth to allow for a wide range of operating conditions, an output circuit suited to drive most recorders and an accurate built-in output indicator. When used with the proper accessories, it can measure antenna patterns over a dynamic range in excess of 40 db with an accuracy of 0.1 db/10 db. Typical patterns so measured are shown in Figures 11 and 12. It can be used to measure insertion loss in r.f. systems up to 80 db with slightly reduced accuracy.

Acknowledgment

The author would like to acknowledge the contributions of Dr. Gunther U. Sorger, Mr. Bruno O. Weinschel and Dr. Samuel J. Raff who are responsible for much of the work reported in this paper.

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A 3-MEGAWATT, 15-KILOWATT S-BAND AMPLITRO

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FRANK ZAWADA

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SPENCER LABORATORIES
BURLINGTON, MASS.

A crossed field, continuous cathode Amplitron capable of producing a 3 Megawatt, 10 microsecond RF pulse under .005 duty cycle conditions is described. Throughout its operating frequency band, which extends from 2900 to 3100 Mc efficiencies of 75 percent are commonly observed. The RF gain is 8 db under rated conditions but gains as high as 15 db can be obtained at lower peak power outputs. Phase pushing figures of 0.5 degree for a 1 percent variation in anode current are typical of the design.

The cylindrical RF circuit is comprised of a non-reentrant strapped ladder line matched at each end to standard S-band waveguide. Operation in the backward wave fundamental is achieved in a frequency region somewhat removed from the circuit's lower cutoff frequency.

A most unusual and important property of the tube is its capability of heaterless operation. No cathode warmup period is required since satisfactory starting will ensue whenever RF drive is present prior to application of the modulating pulse. Among several benefits arising from heaterless operation lies the promise of exceptionally long tube life.

Introduction

Expanding requirements for frequency flexibility and sophistication in many military radars have tended to center interest lately upon the master-oscillator-power-amplifier chain. The system designer, confronted by these requirements and faced with a growing need for higher radiated power levels, must exercise great care in electron tube selection if he is to achieve a compact, reliable transmitter. One type of tube which offers distinct advantages for many applications and which possesses the unique combination of broadband operation at high efficiency, is the Amplitron.[1]

The particular tube to be discussed here, designated the QK622, is one of several high power Amplitrons that have been developed since W. C. Brown first introduced the device [2,3] in 1955. Its development, under sponsorship of the United States Navy Bureau of Ships, has recently been completed. A typical member of the Amplitron family, the QK622 provides stable moderately broadband operation without mechanical or electrical adjustment when used in conjunction with suitable modulating equipment. Figure 1 shows the more important electrical characteristics of the tube.

QK622 CHARACTERISTICS

FREQUENCY	2900 to 3100 megacycles
PEAK POWER OUTPUT	3 megawatts
AVERAGE POWER OUTPUT	15 kilowatts
PULSE DURATION	10 microseconds
PEAK RF INPUT POWER	475 kilowatts
PEAK ANODE VOLTAGE	50 to 55 kilovolts
EFFICIENCY	75 percent

$$\text{EFFICIENCY} \equiv \frac{P_o - P_d}{P_{mod}}$$

Figure 1 — Normal Operating Characteristics of the QK622 Amplitron

A peak power output of 3 megawatts and an average power output of 15 kilowatts are obtained with a pulse duration of 10 μsec. The efficiency of the tube when operated under these conditions is nominally 75% where efficiency is defined as the quotient $\frac{P_a}{P_{mod}}$. Here, P_a represents the power contribution of the Amplitron stage its or the difference between the output and drive pow and P_{mod} represents the pulsed d-c input power suppl by the modulator. In covering the frequency band fr 2900 to 3100 Mc the peak anode voltage ranges from to 55 kV as a result of the backward wave interact employed. The peak RF input power of 475 kilow corresponds to the normal 8 db gain of the QK622 at 3 Mw output level.

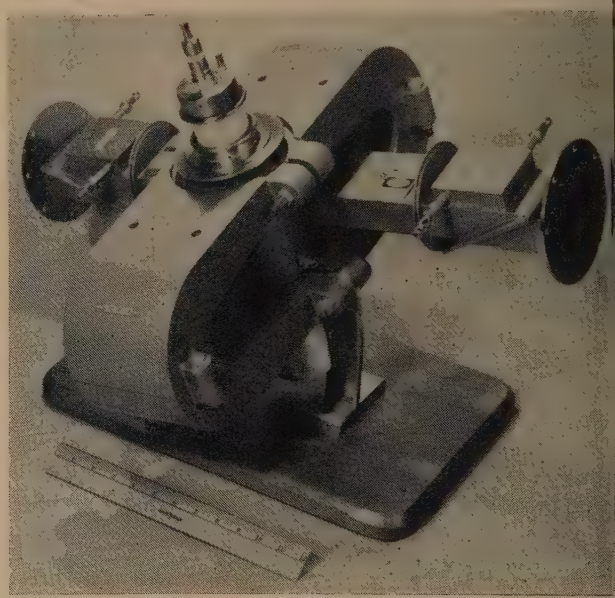


Figure 2 — The QK622 Amplitron

Physical Details and Circuit Theory

The tube itself is shown in Figure 2. RF drive po applied at the input flange on the extreme right pa thru a slanted window assembly. It is then conduc along the S-band waveguide run and into the slow w network, which is contained within the anode cylinde the center of the photograph. The output signal then p agates to the flange at the extreme left. An axial magn field is provided by the permanent magnet, an cathode terminal is provided on the ceramic input bush A liquid coolant can be supplied to the RF window semblies, each of which utilizes a cylindrical ceramic

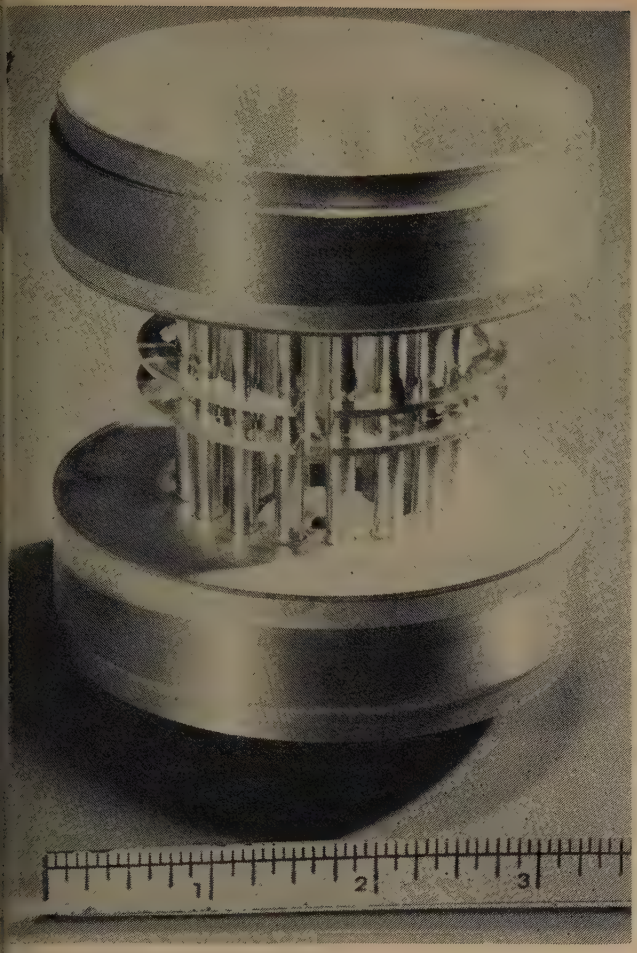


Figure 3 — The QK622 Slow Wave Network

brazed to a metallic plate. The assembly thus formed is placed across the waveguide at a 25° angle with respect to the broad wall, yielding a VSWR less than 1.05 to 1 over the band from 2800 Mc to 3200 Mc.

Figure 3 shows details of the tube's slow wave network. Here, the 16-section strapped bar line is comprised of a parallel plane transmission line at the axial center of the structure and a series of stub lines fabricated from copper tubing. Transducers, not shown, provide coupling between the severed ends of the parallel lines and the standard S-band waveguide. The stub lines are terminated at both ends in plane conductors. A liquid coolant is circulated from the cylindrical chamber at one end through the several tubes to a similar chamber at the other end. Equivalent circuit-wise, the network may be represented as a lattice structure.

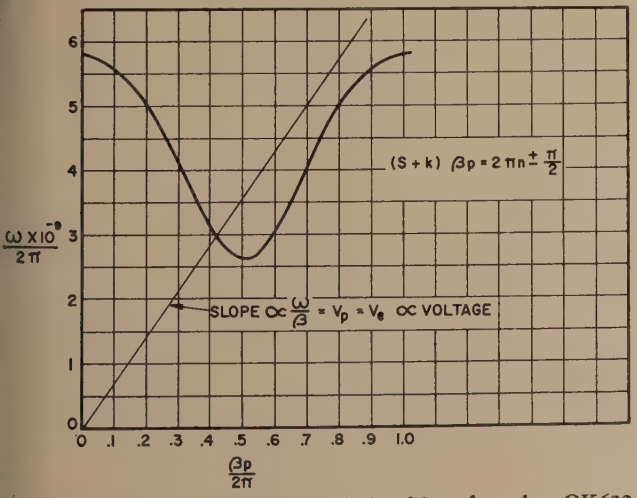


Figure 4 — Frequency-Phase Relationships for the QK622 Amplitron

The input and output planes of the tube are isolated electrically by a one-pitch drift section (between the severed ends of the straps). On the other hand the electron stream is reentrant and the effects of this reentrancy are twofold. First, it is an important factor contributing to the high efficiency of the device and secondly, it restricts the operating bandwidth. With the aid of Figure 4, the basis for this frequency limitation may be explained.

The ω-β diagram which describes the circuit shows that operation is in the backward wave fundamental and that the pass band width is 2.2 to 1. The mid-band operating point, corresponding to a phase shift of .412 wavelengths per section, is indicated by the intersection of the operating line with the characteristic.

Now, defining S as the number of network sections between the input and output planes, k as the length of the drift section as measured in circuit pitches p, β as the circuit's phase constant, and n as any integer, the reentrancy equation

$$(S + k)\ \beta p = 2\pi n \pm \frac{\pi}{2}$$

may be written to define the extremes of preferred segments of the ω-β diagram. In writing this equation it has been assumed that the electron velocity at the outer edge of the space charge cloud has been made equal to the circuit's phase velocity and that there is no change in electron velocity in the drift region. Moreover, the experimental observation that electrons in a space-charge spoke may lead or lag the circuit wave by as much as $\frac{\pi}{2}$ radians has been used.

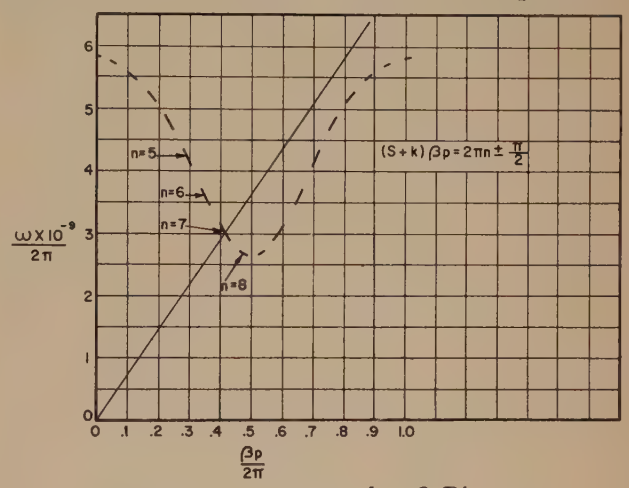


Figure 5 — The Segmented ω-β Diagram

If reentrance phase is defined as the relative phase difference between an electron spoke and the circuit wave at the output, it is found that the lowest frequency at which the reentrancy phase is 0° occurs when n = 8. Other 0° reentrancy phases then occur at descending integer values of n. The usable segments of the ω-β diagram, as determined by means of the reentrancy equation, are shown in Figure 5. In the QK622 the n = 7 segment is used for operation because it yields greater bandwidth than the n = 8 segment. However, since the latter lies in a lower voltage region, it is found that a small amount of low frequency energy appears at the beginning and end of each pulse. The n = 6 segment is not used, even though it

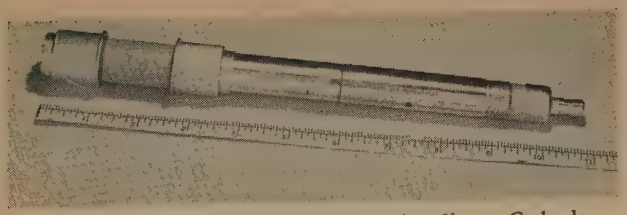


Figure 6 — Details of the QK622 Amplitron Cathode

would yield even greater bandwidth, because spurious energy would then be likely in both the n = 8 and n = 7 bands.

Note that by varying k, the drift section length, the various segments may be arbitrarily shifted up or down along the ω-β characteristic. Here k has been adjusted to provide a reentrancy phase of π radians at the lower cutoff frequency of the filter, thus minimizing the possibility of self-oscillations at that frequency, where matching is difficult.

The cathode assembly, shown in Figure 6, utilizes a tungsten-thoria cermet emitter operating at an emission current density of 2.9 amperes/cm^2. A tungsten heater is used for outgassing of the structure on the vacuum pump but it is not used thereafter since the tube will start reliably and operate under so-called "cold cathode" conditions. Consider the conditions existing at the time an Amplitron is pulsed. As it must be for proper operation, the RF drive pulse has previously been applied, creating an RF electric field in the interaction space of the tube. This RF electric field ionizes the residual gas molecules in its vicinity. (Incidentally, the density of this residual gas is approximately 3×10^8 molecules/cm^3 in a tube evacuated to a pressure of 10^{-8} mm Hg.). When the high voltage pulse is then applied, many of the free electrons will find themselves at phase positions in which they may extract energy from the RF field and, in so doing, they are forced into the cathode from which secondary electrons are ejected. Thus, anode current is initiated and maintained.

Performance Characteristics

Typical QK622 V-I characteristics are presented in Figure 7. Load lines typical of hard and soft tube pulsers have been dotted in to indicate the effect of variations in drive frequency. In covering the band from 2900 to 3100 Mc the voltage and current will adjust themselves when a line type modulator is used so that the modulator power input is approximately constant. Since Amplitron efficiency is not a primary function of frequency, the RF

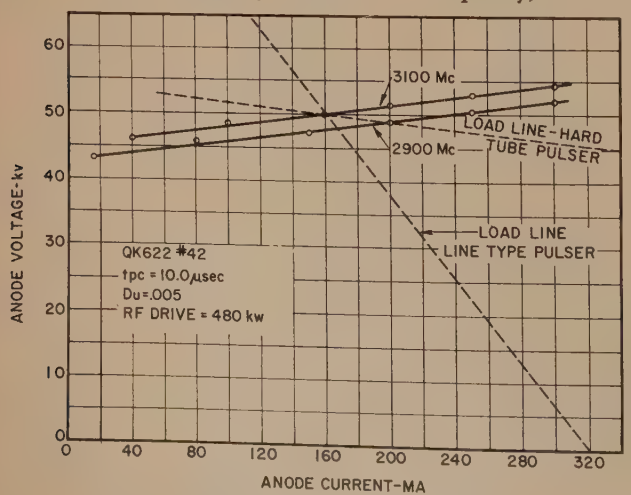


Figure 7 — V-I Characteristics

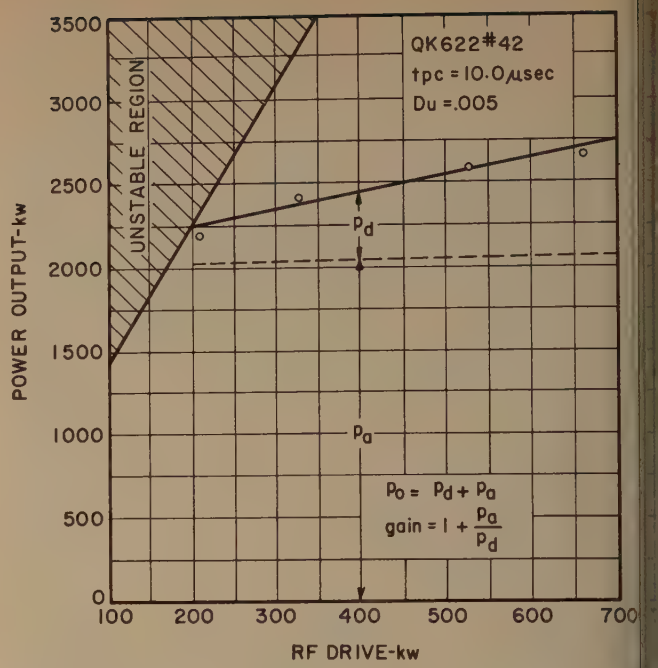


Figure 8 — Peak Power Output as a Function of Peak RF Drive Power

power output under these conditions will be nearly constant. On the other hand the hard tube pulser will, uncompensated, result in large Amplitron current fluctuations and the consequent effect upon output power will be undesirable. Fortunately, however, some sort of power sensing device or servo control can be provided to secure the necessary degree of modulator regulation.

In Figure 8, RF output versus RF drive is indicated for a constant modulator input. Here it can be seen that in the operating range the output is given by the RF input p_d, plus the power contributed by the Amplitron p_a. As one increases drive power the major effects are (1) that the additional drive appears at the output and (2) that a slight increase in operating efficiency occurs as evidenced by the broken curve of p_a. In the cross-hatched area at the left, spurious oscillations are experienced as a result of insufficient RF drive power. When the approximate equation given for power output is converted into a gain relationship, it is apparent that high gains can be attained only with reduced locking power and that efficiency is not a function of gain since p_a varies but little with p_d.

Figure 9 shows how operating frequency limits are actually determined. With RF input power constant, the modulator power input is increased at each frequency, as in curve A, until unlocking occurs. After establishment of a guard region B, curve C may be drawn to indicate

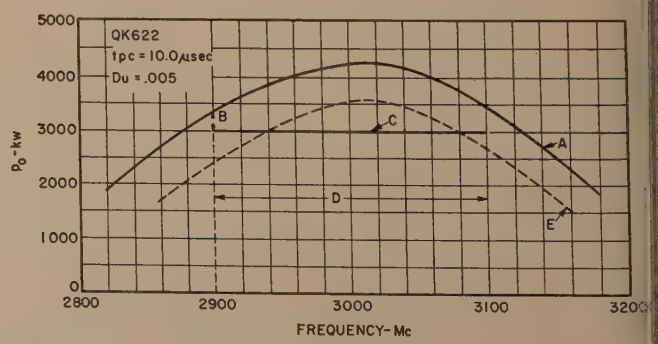


Figure 9 — Bandwidth Characteristics of the Amplitron

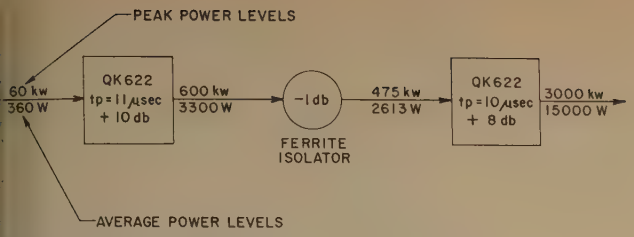


Figure 10 — Block Diagram of the QK622 Chain Test Setup

power output for a constant modulator power input. The bandwidth, D, for that condition of operation is thereby determined. Note that the Amplitron power output is then essentially constant throughout the entire rated band. Curve E shows the equivalent of curve A for a lower drive power and it indicates that, under such conditions, full power can be realized only over a narrower band or alternatively that reduced power is available over the full band.

The normal laboratory test setup for the QK622 is shown in Figure 10. Two tubes are operated in cascade with the interstage isolation necessary to protect the low power stages provided by a ferrite isolator. With a 12 μsec 60 kw input signal obtained from an RK5657 magnetron, the first stage operates at 10 db gain and at 11 μsec pulse duration and delivers, after a loss of approximately 1 db in the isolator, 475 kw to the second stage. There an additional 8 db gain is provided at a 10 μsec pulse duration, .005 duty cycle, so that the final output power is 3 Mw peak and 15 kW average. Typical performance data obtained under these conditions are shown in Figures 11 and 12. Figure 11 is a plot of peak power output versus frequency for a constant anode current of 50 peak amperes and an RF drive of 480 kw. Figure 12 shows corresponding data for the input stage when operated at a gain of approximately 12.5 db. Under the latter conditions, the voltage varies between 48 and 53 kV and the efficiency remains close to 70%. Note the small variation in output power with frequency.

The QK622, when operated under the chain setup conditions, has delivered as much as 20.5 kW of average power output, and it was then limited only by the modulator input available. Also, under these conditions, operating efficiencies in excess of 80% have been recorded and, in fact, it is unusual for the efficiency to fall below 70%. At .001 duty cycle, and with an RF drive of 3Mw the QK622 has yielded a peak output power of 8.8 Mw.

At the time of publication, two QK622 Amplitron chains had undergone formal life test. In each case, stable operation under full rated conditions was obtained for a period greater than 1000 hours.

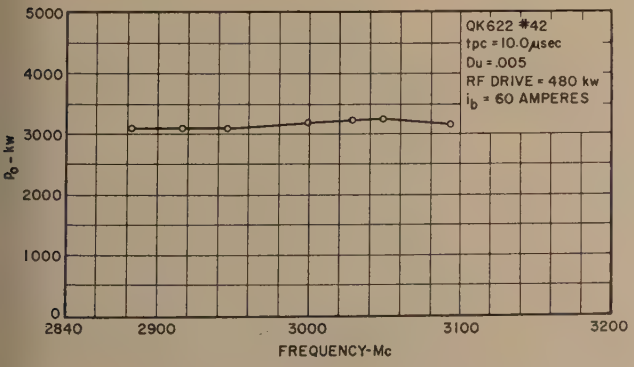


Figure 11 — Peak Power Output as a Function of Frequency

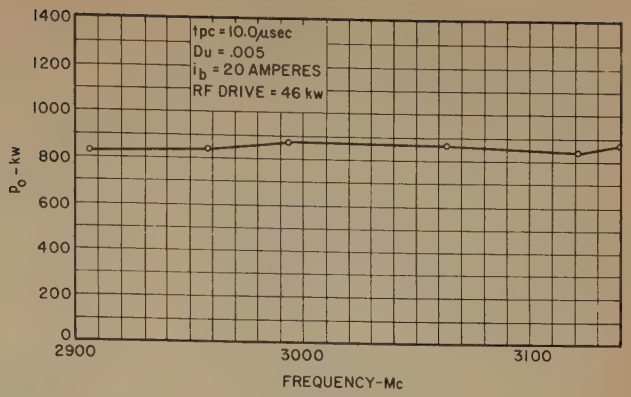


Figure 12 — Peak Power Output as a Function of Frequency

Finally there is the matter of stability. Because the tube utilizes a matched RF structure, its RF voltages are low and its pulse stability, or freedom from internal arcing, is excellent. Missing pulse percentages in this tube type are less than .05%. Moreover phase pushing measurements have consistently yielded values close to 0.5° of phase variation for a 1% variation in anode current.

Conclusion

In evaluating the merits of the QK622 Amplitron for a given application one might review its advantages and limitations. Among the disadvantages one would find first that a small amount of spurious energy is generated during the rise and fall times of the applied voltage pulse. Amplitrons, however, operate well with short rise times so that this difficulty can be minimized. Secondly, linear amplification is not possible since the Amplitron has no linear range. As a limitation the relatively low gain of the QK622 might also be cited but it should be recalled that because of the device's low insertion loss, high efficiency, and compact size, the cascading of tubes can offset this limitation.

The attractive features of the QK622, on the other hand, are numerous. A list of them would include the following:

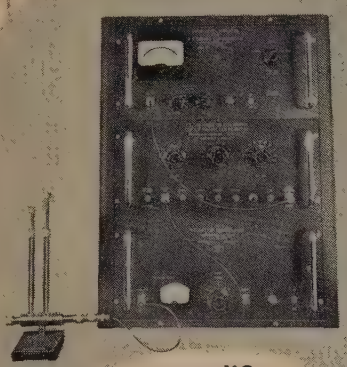
- High power output, limited only by the RF output window
- High efficiency
- Low operating voltage
- Excellent phase and pulse stability
- Low insertion loss
- Capability of heaterless operation
- Capability of wide pulse operation
- Simple compact construction.

As a result of these properties, the QK622 is believed to be eminently suited to applications in high power radar systems and in linear accelerators. Moreover, its design principles may readily be extended to the realization of super power, high efficiency tubes of the future.

Footnotes

1. Weil, T. A., "Applying the Amplitron and Stabilotron to MTI Radar Systems," 1958 IRE National Convention Record, Part 5, pp. 120-130.
2. Brown, W. C., "Description and Operating Characteristics of the Platinotron — A New Microwave Tube Device," Proceedings of the I.R.E., Vol. 45, No. 9, September 1957.
3. Brown, W. C., "Platinotron Increases Search Radar Range," Electronics, August 1, 1957.

MEASURE ATTENUATION
DIRECTLY up to 30 db
WEINSCHEL
single channel INSERTION LOSS TEST SET
Maximum systems error: .1 db
Resolution about .02 db
Frequency Range: 20 MCS to 90,000 MCS
KEY INSTRUMENTS



Bolometer Preamplifier, Model BA-1B
Features wide dynamic linear range, extremely low noise level, cannot burn out barretter.

AF Substitution Attenuator for RF Square Law Detector, Model CF-1
Calibrated directly in rf power ratios; has high input impedance, low output impedance.

Audio Level Indicator, Model IN-1
Precharging circuit reduces required observation time. Has adjustable indicator time constant, low noise level.

Double Stub Tuner, DS-109
For theory, method, required instruments and recommended accessories, request Application Notes #1.

Weinschel Fixed Coaxial Attenuators cover the frequency range of DC to 12 KMC. Write for complete catalog, specifying frequency range of interest.

WEINSCHEL ®
Weinschel Engineering
KENSINGTON, MARYLAND

CIRCLE READER SERVICE CARD 20

Industry News

(*Continued from page 22*)

Laboratory at Long Beach, California. Other experience was with Bell Telephone Company, Majestic Radio and TV, and McGraw Electric. He took his Degree in Electrical Engineering at the University of Minnesota and has done graduate work at Colorado A & M.

• • •

NEW SALES MANAGER FOR BOMAC

Bomac Laboratories, Inc., Salem Road, Beverly, Mass. recently announced that Mr. Cyrus W. Haller has joined the company in the position of general sales manager.

Prior to becoming associated with Bomac, Mr. Haller was a manufacturer's representative for the General Electric Co. throughout New England on closed circuit television.

Mr. Haller attended both the University of Pennsylvania and the Massachusetts Institute of Technology.

• • •

HEWLETT-PACKARD BUYS BOONTON

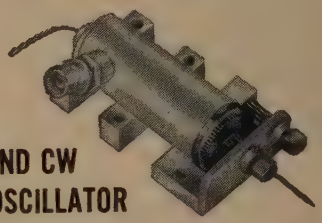
Mr. David Packard, President of Hewlett-Packard Company, and Dr. George A. Downsbrough, President of Boonton Radio Corporation, Boonton, New Jersey have jointly announced that the Hewlett-Packard Company has acquired all of the outstanding stock of Boonton Radio Corporation.

The arrangements call for the transfer of -hp- stock for all outstanding shares of Boonton Radio Corporation stock. Under the terms of agreement Boonton Radio would become a wholly owned subsidiary of the Hewlett-Packard Company.

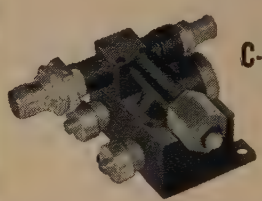
Boonton Radio Corporation, located in Boonton, New Jersey was founded in 1935 by William D. Loughlin. The company designs and manufactures signal generators and similar instruments.

Since the death of the founder in 1950, the company has continued operations under the direction of Dr. Downsbrough. Boonton has an annual sales volume of $2.5 million. It has approximately 150 employees.

NEW!
C-Band *System-Tested* MICROWAVE COMPONENTS
Engineered to meet complete Military Missile Specifications



C-BAND CW OSCILLATOR
- Minimum 3 mw Power Output
- Adjustable Tuning over a range of 500 mc
- Tube—Triode GZ 5139
- Miniaturized—only 4" long, 1¾" wide, 1¼" high (excluding connector)



C-BAND BEACON FRONT END ASSEMBLY
- An exceptionally compact, lightweight unit, featuring low loss and ultra-high selectivity.
- Extremely small—only 2½" x 2½" x 2"

C-BAND FILTER MIXER DIPLEXER

- Mixer and Diplexer (non-tunable) operate as an integral part of the Filter
- Unit features minimum Insertion Loss, Rejection Bandwidth and Input VSWR
- Tuning Range—minimum 500 mc

WRITE for prices and delivery.

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ACF INDUSTRIES INCORPORATED
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11 Park Place, Paramus, N. J.

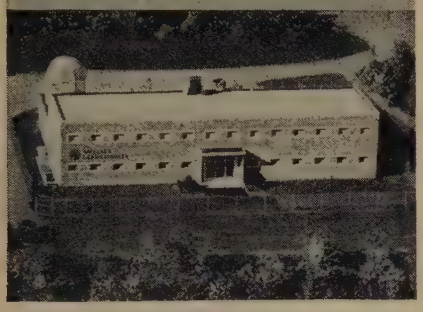
CIRCLE READER SERVICE CARD 21

Main Office and Microwave Laboratory Great Neck, N.Y.

In the field of microwave engineering, Wheeler Laboratories occupies a unique position as an independent laboratory devoted exclusively to consulting and development.

WHEELER LABORATORIES, INC.
ON LONG ISLAND

Antenna Laboratory and Test Range Smithtown, N.Y.



As a service to many prominent laboratories and manufacturers, WL has designed antennas, waveguide components, and microwave assemblies. Your inquiries are invited.

Harold A. Wheeler and Engineering Staff

CIRCLE READER SERVICE CARD 22

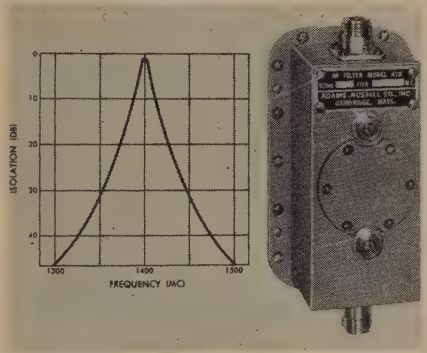
E. W. HEROLD V.P. FOR RESEARCH AT VARIAN

The appointment of Edward W. Herold Vice President for Research was announced recently by H. Myrl Stearns, president of Varian Associates.

Herold has a B.S. degree in physics from e University of Virginia (1930) and a S. degree in the same subject from lytechnic Institute of Brooklyn (1942). so, he is a member of Phi Beta Kappa, gma Xi and the American Physical Soety. He is an editorial board member, rmer director and Fellow of the Instite of Radio Engineers.

NEW PRODUCTS

RUGGED MIDGET CAVITY FILTER IN 400-2000 MC RANGE



Adams-Russell Co., Inc., of Cambridge, Massachusetts, announces the introduction of their new Midget Cavity Filter, Model 410, available for any frequency in the 400-2000 Mc range. This rugged dual cavity is tunable over a limited range of from 3 to 10% depending on center frequency. It is airtight and will withstand shock, vibration, and temperature extremes. Response curve and bandwidth are essentially the same for any pass frequency. Other features include: **Power,** 20-50 watts, according to pass frequency; **Insertion Loss,** 1 db; 3 db **Bandwidth,** 8 Mc; 30 db **Bandwidth,** 60 Mc; **Size,** 3"x3"x 5½"; **Weight,** 28 ounces.

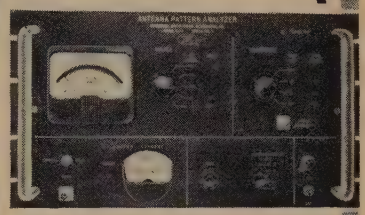
CIRCLE READER SERVICE CARD 101

WEINSCHEL
ANTENNA PATTERN ANALYZER MODEL BA-7

Measure 45 db (r. f.) in one step using a maximum of 1 microwatt r. f. power*

*100% square wave modulated at 1000 cps ± .1 cps. Observation time approximately 45 seconds for 45 db; only .2 seconds for 30 db.

Bandwidth variable from 2 to 15 cps with constant gain



MODEL BA-7

The BA-7 is the heart of a video detector system designed primarily for r. f. crystals. For greater versatility, a d. c. biasing circuit is included to permit use of conventional barretters, requiring a d. c. bias between 0 and 10 ma. The unit can be used to measure very high power ratios such as occur in making antenna pattern measurements, to determine the rejection coefficients of r. f. filters, and to calibrate attenuators. It has a wide dynamic linear range, a low noise level, and a wide r. f. frequency range where video crystal mounts are available.

For complete specifications, write for Bulletin No. 141.

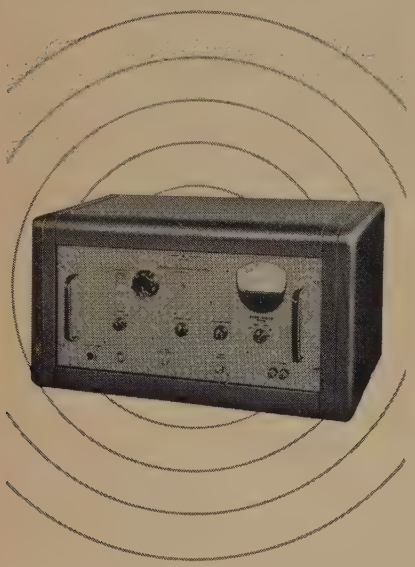
Weinschel Fixed Coaxial Attenuators cover the frequency range of DC to 12.4 KMC. Write for complete catalog, specifying frequency range of interest.

WE CO

Weinschel Engineering
KENSINGTON, MARYLAND

CIRCLE READER SERVICE CARD 23

PRECISION TEST RECEIVER



Sensitive Detection of Microwave Energy

The AIL Type 130 Precision Test Receiver (30 and 60 Mc standard units available) is a versatile instrument combining a high gain, low-noise figure receiver and a secondary standard of attenuation. It can be used wherever accurate measurements of the differences of r-f and i-f power levels are required. A few typical applications are: noise-figure measurement, measuring characteristics of directional couplers, calibration of r-f attenuators and measurement of selectivity characteristics.

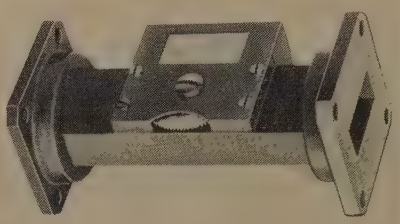
Detailed literature is available on request.

AIRBORNE INSTRUMENTS LABORATORY
1345 NEW YORK AVENUE
HUNTINGTON STATION, L. I., N. Y.
A DIVISION OF CUTLER-HAMMER, INC.

CIRCLE READER SERVICE CARD 24

A NEW VARIABLE FIXED ATTENUATOR

The development of a lightweight, rugged, and inexpensive X-band variable fixed attenuator pad has been announced by Waveline, Inc., Caldwell, N. J.



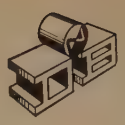
The type 609 makes use of bilaterally matched unbreakable attenuator elements secured by metallic eyelets and positioned by a precision mechanism. The device provides accurate, long life settings over wide ranges of temperature and humidity.

Constructed of RG-67/U aluminum waveguide and equipped with UG-135/U standard flanges, the type 609 weighs only 3½ ounces. Over the frequency range 8.2 to 12.4 KMC, the attenuation range is 0.3 to 30.0 db with a maximum VSWR of 1.15. The unit is 3½" long and is finished with Iridite.

The type 609 has a small quantity price of $50 and is available from stock to 2 weeks.

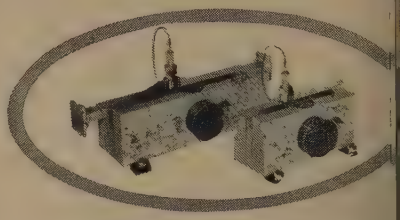
CIRCLE READER SERVICE CARD 102

More NEW PRODUCTS *on page 51*



STANDING WAVE DETECTORS

—exceptionally accurc



You get the accuracy that resul from perfect parallelism betwee slot and waveguide axis... betwee probe travel and waveguide ax Only 30 seconds needed to equip D-B slotted line to measure adj cent frequency bands. Range: 5 KMC to 140 KMC—covered by *minimum* of units, to stretch yo budget. Literature on request.

DE MORNAY BONARDI

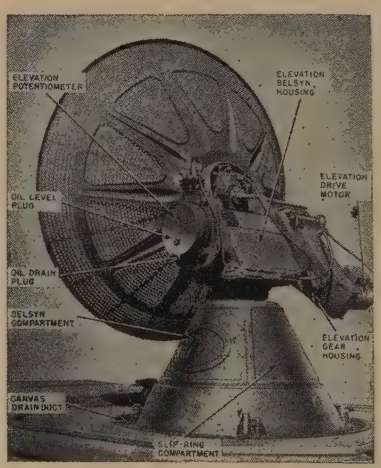
DE MORNAY–BONARI

780 SOUTH ARROYO PARKWAY • PASADENA, CA

CIRCLE READER SERVICE CARD

RADIO RESEARCH INSTRUMENT CO.

550 FIFTH AVE. NEW YORK JUDSON 6-4691



ANTENNA PEDESTAL SCR 584—MP 61B

Full azimuth and elevation sweeps. 360 degrees in azimuth. 210 degrees in elevation. Accurate to 1 mil. over system. Complete for full tracking response. Includes pedestal drives, selsyns, potentiometers, drive motors, control amplidynes. Excellent used condition. This is the first time these pedestals have been available for purchase. Limited quantity in stock for immediate shipment. Ideal for antenna pattern ranges, radar systems, radio astronomy, any project requiring accurate response in elevation and azimuth. Complete description in McGraw-Hill Radiation Laboratory Series, Volume 1, page 284 and page 209, and Volume 26, page 233.

AUTOMATIC TRACKING RADAR

Complete system for missile, aircraft, satelite, balloon tracking to altitude of 100 miles or better. Housed in own van 20 ft. x 12 ft. x 8 ft. As new. Write us.

2 MEGAWATT PULSER

Supplies 2 megawatt to magnetron at a pulse duration of 2 microsec. Fixed gap type. Uses 4C35 hydrogen thyratron. Brand new complete. G.E. $1150.00.

F-28/APN-19 FILTER CAVITY

Jan. spec: Tuneable 2700-2900mc, 1.5db max. loss at ctr freq over band. Details: Insertion loss variable. Single tuned filter for freq channelling in radar beacon. Invar center tuning conductor ¾ wavelength. New $37.50 each.

⅞" RIGID COAX. RG44/U 50 ohm, standard fittings, 10cm stub supported. 12 ft. lengths. Silver plated. New $34.50 each. 12 ft. length. Right angle bends $6 ea.

KLYSTRON MOUNTS

3CM. Precision Tube Mount. Waveline model 688, X band shielded klystron mount PRD signal generator type. Complete with variable glass vane attenuator. Brand new. $205. list. Price $45.00.
S. band. Type N output. Tunable over entire band. For Shepard type tube i.e. 726 w/socket & tube clamp. Mfg. GE. New, $15.00.

TOPWALL HYBRID JUNCTION. 8500-9600mc 1x.5 wg size. Broad banded better than 16%. Aluminum casting. $15.00 new. Crossover output, 1x.5 wg size. $5.00 new.
BROAD BAND BAL MIXER using short slot-hybrid. Pound type broad band dual balanced crystal holder. 1x.5 wg size. $25.00 new.

VD-2 PPI REPEATER

Takes any radar PPI info and displays on 7" tube compact floor standing console. Complete rotating yoke assy. 115V 6DCY AC Pwr. 4, 20, 80, 200 mile ranges. Brand new w/Inst. Bk. $385.

AN/APS-10 3CM. X BAND RADAR

Complete RF head including transmitter, receiver, modulator. Uses 2J42 magnetron. Fully described in MIT Rad. Lab. Series Vol. I, pps. 616-625 and Vol. II, pps. 171-185. $375.00. Complete X band radar system also avail. incl. 360 deg. antenna, PPI, sync, pwr supply. Similar to $17,000 weather radar now in use by airlines. $750 complete.

CIRCLE READER SERVICE CARD 26

PULSE

GENERATION

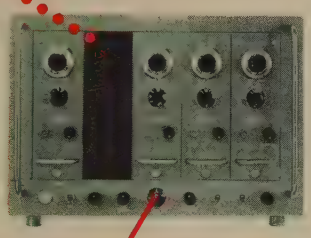
Five plug-in pulse generators provide any code—1 to 5 pulses—with completely independent adjustment of width and delay for each pulse.

PULSE DELAY:
variable 0 to 300 microseconds

PULSE WIDTH:
variable 0.2 to 2 microseconds

PULSE TIME MODULATION:
Sensitivity, 2 volts RMS per microsecond

CODED MULTIPULSE GENERATOR
Model MP-1A



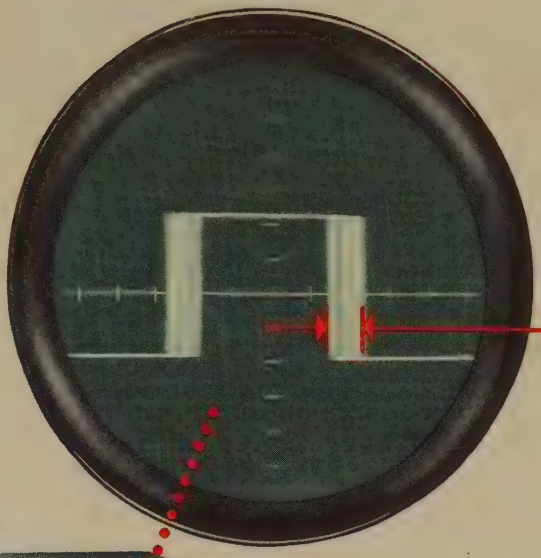
E AND DECAY TIME:
microsecond

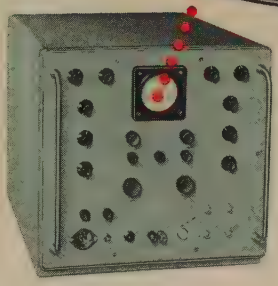
GROUP REPETITION RATE:
10 to 10,000 pps

Used to modulate r-f signal generators with coded pulse groups. Internal or external sync; square wave output, 10 to 10,000 pps. Pulses can be independently pulse-time modulated by external signal.

APPLICATIONS: Design and testing of missiles, radar, beacons, IFF, telemetry, etc.

TESTING



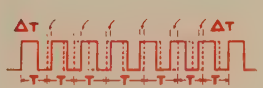


PULSE JITTER TESTER
Model PJ-1

Displays the magnitude and waveform of pulse jitter (time deviation) in rate generators, pulse width modulators, encoding devices and precision time generators.

MEASURES:

PULSE WIDTH JITTER: Peak-to-peak time deviation (△T) at the half-amplitude points, between the leading and trailing edges of a recurrent pulse having a nominal width represented as "T" in the diagram at left.



ABSOLUTE JITTER: Time deviation (△T) at the half-amplitude points, from leading edge to leading edge of successive pulses (of duration "T" in the diagram) in a pulse train.

RELATIVE JITTER: Peak-to-peak time deviation (△T) at half-amplitude points of the leading edge of one pulse to the leading edge of a reference pulse. The time difference between the two is "T" in the diagram.

Repetition Rate Jitter: 5 millimicroseconds to 100 microseconds full scale. **Relative or Width Jitter:** 5, 10, 100 millimicroseconds.

REE LIFETIME SERVICE
ON ALL POLARAD
INSTRUMENTS

MAIL THIS CARD
for complete specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes on Microwave Measurements"

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esentatives in principal cities

POLARAD ELECTRONICS CORPORATION:

Please send me information and specifications on:

POLARAD

- ☐ Model MP-1A Coded Multi-Pulse Generator
- ☐ Model PJ-1 Pulse Jitter Tester
- ☐ Model VS-2 Rapid-Scan Ratio-Scope (see reverse side of page)
- MJ ☐ Model ESG Electronic Sweep Generator (see reverse side of page)

My application is:_____

Name_____

Title_____ Dept._____

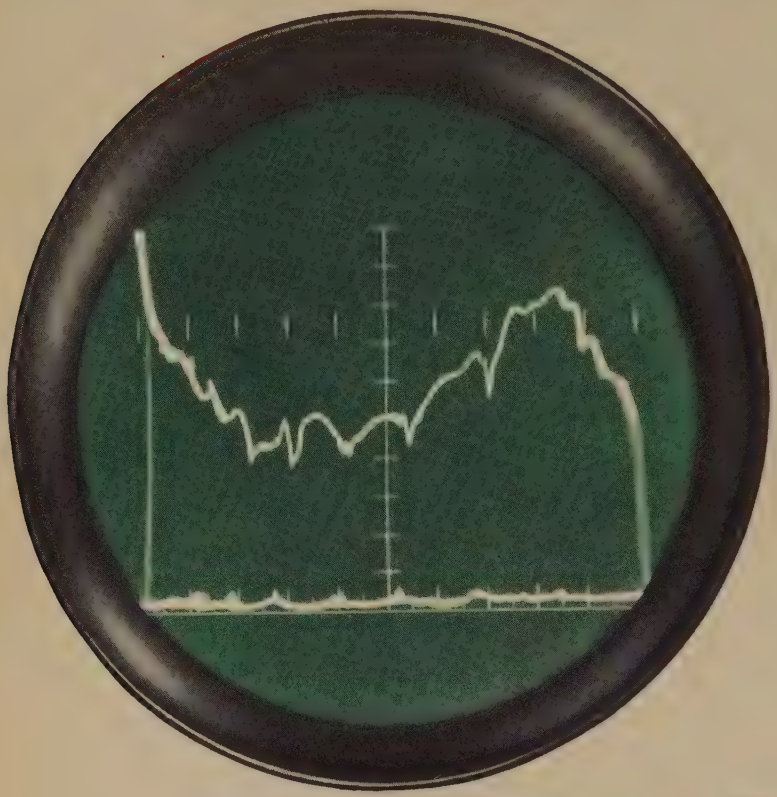
Company_____

Address_____

City_____ Zone____ State_____

INSTANTANEOUS MICROWAVE ANALYS

SINGLE FREQUENCY OR OVER A FULL OCTAVE



Complete VSWR pattern of a microwave component over an entire frequency octave is displayed on a calibrated 7" CRT.

Instantaneous measurements at a single frequency or over an entire swept frequency range can be obtained with an Electronic Sweep Generator and a Rapid-Scan Ratio Scope

VSWR at any single frequency is indicated on the Ratio-Scope front panel meter.

Saves Engineering Manhours

1,000 to 15,000 mc

ELECTRONIC SWEEP GENERATOR

Model ESG 1,000-15,000 mc

Sweep width continuously adjustable, single frequency to an entire octave.

RAPID SCAN RATIO-SCOPE

Model VS-2

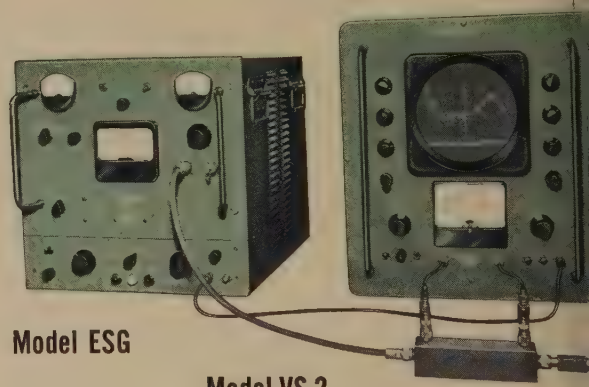
Displays the ratio of two input signals; gives visual plot of VSWR as a function of frequency.

Measure and Analyze:

VSWR, transmission and reflection coefficients, gain and attenuation, image rejection, sensitivity, selectivity, bandwidth and filter characteristics, antenna patterns, etc.

Microwave Components:

Radars, receivers, beacons, waveguides, antennas, pads, terminations, couplings and hybrid junctions, attenuators, crystal mounts, preselectors, amplifiers.



Model ESG

Model VS-2

Typical set-up for measuring VSWR of a microwave component. Directional coupler outputs feed incident and reflected signals separately into the Ratio-Scope. Scope displays the pattern of the ratio between the two inputs over the entire frequency range swept.

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

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First Class Permit No. 18, Long Island City 1, N.Y.

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43-20 34th St., Long Island City 1, N. Y.

POLARAD

MAIL THIS CARD
for complete specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes on Microwave Measurements"

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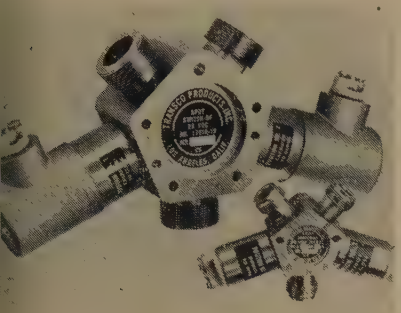
Representatives in principal cities

IEW PRODUCTS

COAXIAL SWITCH BY TRANSCO

Transco Products, Inc., West Los Angeles microwave component manufacturer, is now marketing a "YL" type Coaxial witch for use with RG 117/U and similar bles.



This switch can be supplied with a wide nge of RF connectors including LT, N, 7/8" and TRU. At 4 KMC, VSWR less than 1.4, insertion loss less than 4 db, and the isolation is greater than db.

The new "YL" switch weighs 3 lbs. nd is 9 inches wide. The basic design is e same as the small "Y" type (weight oz., 4" wide) for RG8/U and similar bles, which the company has produced nce 1954 to meet the need for a miniare, light weight, dependable coaxial switch with low VSWR and broad band width.

This "Y" switch is used at frequencies to 11 KMC. Wide flexibility in complex circuit switching is provided by independently operating solenoids. The two-actuator design allows operation as make-before-break or break-before-make. Also, the two RF positions can be both on or off simultaneously. Fail-safe is easily provided by solenoid selection that will switch to a safe position when power is removed.

CIRCLE READER SERVICE CARD 103

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MAGNETRON PULSE MODULATOR

Bomac Laboratories, Inc., Salem Road, Beverly, Mass., has recently announced a new pulse modulator — the BL-P-030. It is capable of powering small magnetrons requiring inputs of up to 10 kw peak at a duty cycle of up to 0.002. Pulse widths from 0.1 to 2 microseconds can be supplied. Meters are provided for pulse voltage, average magnetron current, and magnetron filament current. Jacks are also provided for monitoring peak pulse current, pulse voltage and the trigger repetition rate. Semi-conductors are incorporated resulting in a compact, light, highly reliable modulator. Physical dimensions are 11-¼" W x 5-¾" H x 5-¾" H x 10-½" D.

CIRCLE READER SERVICE CARD 104

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COMPACT TEE CIRCULATOR BY AIRTRON

Airtron, Inc., a division of Litton Industries, announces a new compact Tee Circulator, primarily for miniaturized operation where narrow band usage is suitable. The circulator, initially suggested by Bell Telephone Laboratories and put into practical form by Naval Research Laboratories, is a 3-port unit for numerous airborne applications where space and weight are vital. Two of them joined in an H configuration provide 4-port circulator action for medium power duplexing, and the units have been found ideal for radar beacon applications and duplexing for radar systems where moderate power handling and narrow bands are involved. Such moderate units at C-band have demonstrated 300 KW peak power handling capacity. Insertion loss is 0.5 maximum, normally under .3db; isolation is 15 db minimum, normally in excess of 20 db. They can be furnished at various bands from 3 to 16 Kmc.

CIRCLE READER SERVICE CARD 105

ALL SIZES

MS FLANGES

IN STOCK

THE FINEST QUALITY BRASS AND ALUMINUM STANDARD WAVEGUIDE FLANGES in stock at Formcraft—all precision made to military standards. For rigid and flexible waveguides.

Special flanges to your specifications. Send sketch or blueprint for a quotation.

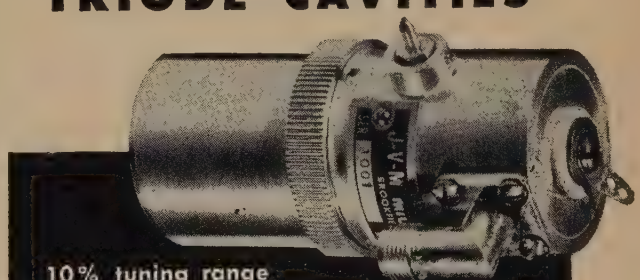
SEND FOR NEW BROCHURE #14B DESCRIBING AND ILLUSTRATING ALL THE STOCK FLANGES

Formcraft TOOL CO.

2465 S. Archer Ave. • Chicago 16, Ill. • CAlumet 5-3173

CIRCLE READER SERVICE CARD 27

NEW! THE MERCURY "10" SERIES TRIODE CAVITIES



10% tuning range

Fully standardized line for design and production . . . Frequency range from 225mc to top existing tube limits

DELIVERY—30 DAYS OR LESS!

Only JVM offers these outstanding engineering advancements—low cost standardized production—off-the-shelf availability—design flexibility and uniform performance.

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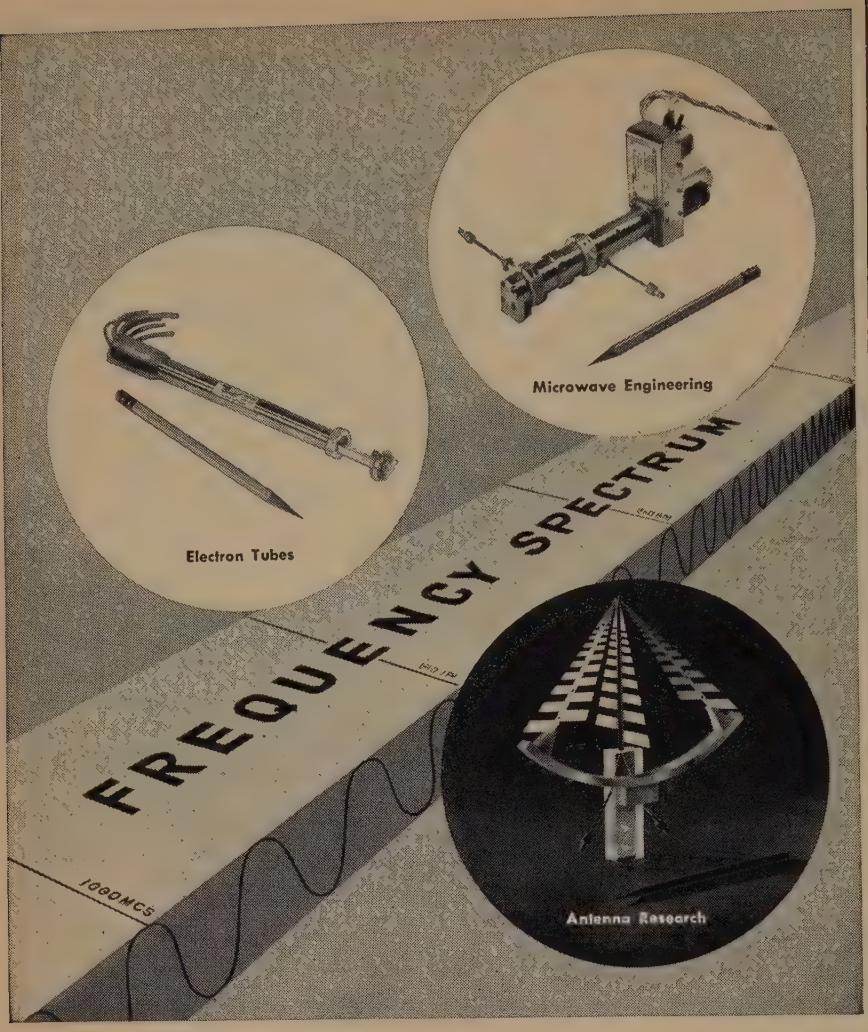

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ITERATURE . . .

CATALOG DESCRIBES UNIQUE TEST SYSTEMS

Automatic testing, microwave and antenna test instrumentation, radome testing systems, and flight simulation equipment are the four categories covered in a new, twelve-page, two-color catalog describing the entire product line of CALIFORNIA TECHNICAL INDUSTRIES division of Textron Inc., Belmont, Calif. The first section includes tape-programmed circuit testers, a card-programmed component tester, a cable tester, and tape reading, punching, and duplicating devices. Direct-reading VSWR systems, magnetron and klystron r-f supplies, and antenna pattern recording accessories such as a variable-polarization antenna and a log-linear amplifier are shown on the microwave pages. Complete systems for automatically recording radome boresight error, percent transmission through the radome, and antenna patterns with and without the radome are illustrated in the third section. The fourth section gives performance specifications for a dynamic altitude simulator and a computer-programmed three-axis flight simulator, both of which are used in evaluating electronic flight-control systems. A price list is also included in the catalog.

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20 PAGE BROCHURE DESCRIBES FERRITES

A new brochure on ferrite materials for the electronics industry is available free of charge from Ferromagnetic Distributors, 15015 Ventura Boulevard, Sherman Oaks, California. The brochure, termed the Ferrite Selector, contains 20 pages of detailed characteristics, physical properties and applications notes on over 37 basic types of ferrites distributed by the firm for Kearfott, TransTech, Raytheon, General Ceramics and Solid State Research. Technical information includes saturation magnetization, Curie temperature, resistivity, dielectric coefficient, and line width. Technical notes describe the key features of each material as they relate to various types of microwave applications.

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BOOKLET ON 140 KMC MICROWAVE EQUIPMENT

A twelve-page, 2-color booklet describing a complete line of millimeter wave components and instruments for performing microwave measurements up to 140 KMC is available from DeMornay-Bonardi, 780 S. Arroyo Parkway, Pasadena, Calif.

Bulletin 140 lists performance characteristics, precision construction features, and dimensioned outline drawings for waveguide sections, detectors, attenuators and terminations, horns, tees, frequency and impedance meters, phase shifters, movable shorts, tuners, and accessories.

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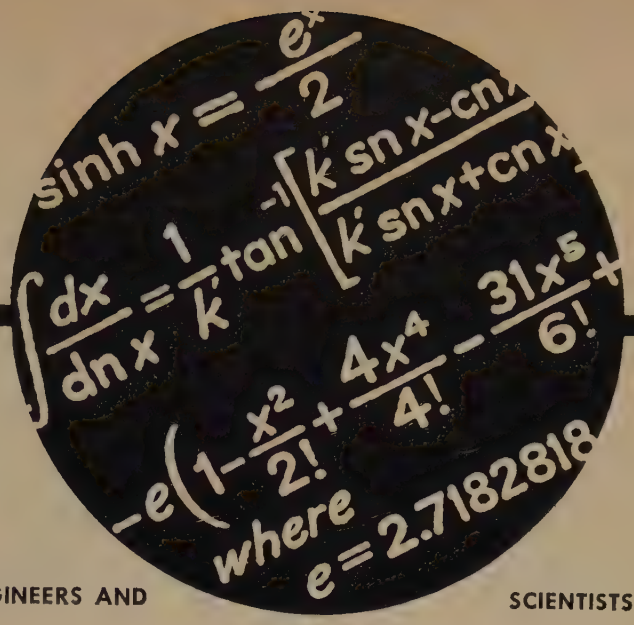

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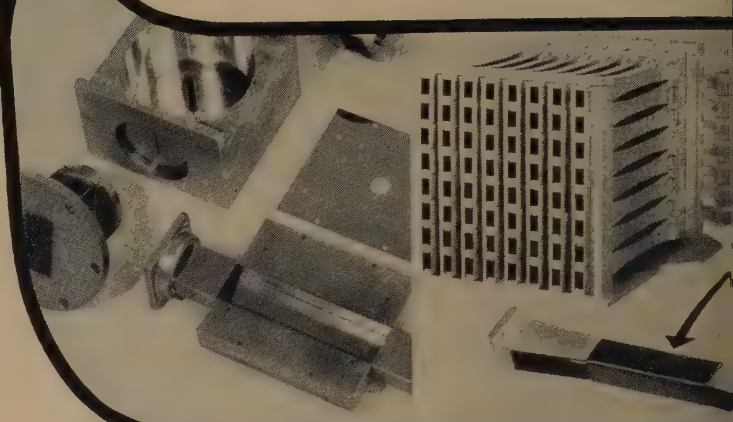

Close-up of Hughes Ferrite Amplifier

X-Band Reciprocal Ferrite Phase-Shif Experimental Electronic Scanner

Modern electronic systems demand a broad range of technical competence. The Hughes Microwave Laboratory has unusually extensive capabilities in the antenna, microwave component, and radome fields. Its activities are co-ordinated in a balanced program of fundamental research, development, design and production engineering.

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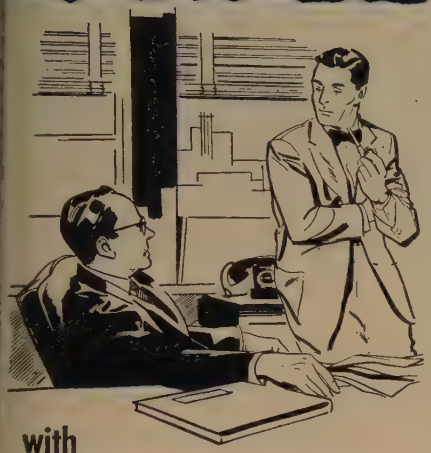

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HEWLETT-PACKARD COMPANY
Palo Alto, California

In describing the rapid growth of electronics firms, probably no other adjective is as overworked as "spectacular." One can hardly review the development of the Hewlett-Packard Company, however, without observing that the company's growth *is* spectacular — in every sense of the word.

Founded in a garage workshop in 1939, Hewlett-Packard today is the world's largest manufacturer of electronic measuring equipment. Its precision instruments are known, used and respected not only throughout the U.S., but in over 30 countries in the Free World.

As the company pauses to observe its 20th anniversary, it can point with justifiable pride to an impressive array of statistics. Sales volume, for example, is running at a $40-million a year clip. Employment is over 2,000 and the company's annual payroll is approaching $13 million. Production facilities are being rapidly expanded; in 1960 the firm's two plants in Palo Alto, Calif., will encompass 570,000 square feet of factory space.

Most impressive, perhaps, is the breadth of the Hewlett-Packard product line. The company now manufactures and sells approximately 400 precision instruments and accessory devices, ranging from simple bolometer mounts selling for less than $100 to sophisticated electronic counters and signal generators costing several thousand dollars. These instruments have a variety of applications, not only as important research tools but as practical design, manufacturing, quality control and maintenance devices for industry.

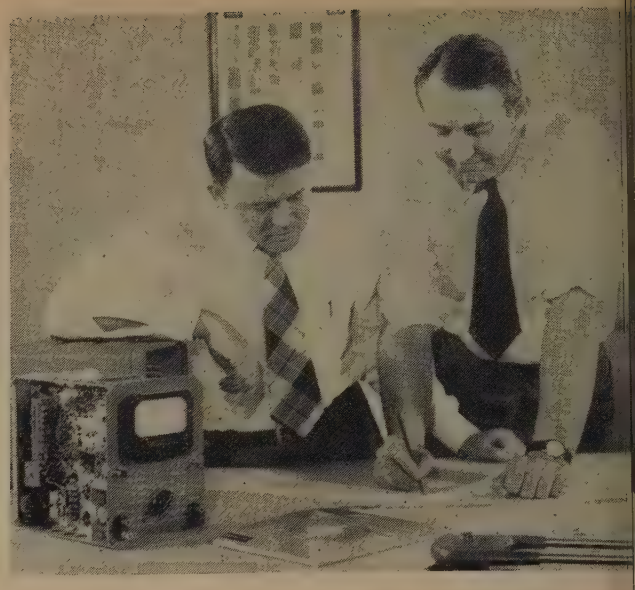
To indicate the magnitude of the Hewlett-Packard line, the company's latest product catalog is a weighty volume comprising 166 pages. It is one of the largest publications of its kind in the electronic industry.

It is difficult, of course, to describe the scope of *-hp-* equipment in a few short paragraphs. Generally speaking, however, the company's products can be broken down into four broad categories:

Microwave equipment — This equipment, consisting of signal generators, power meters and devices for use in waveguide and coaxial systems, is employed in microwave communications, military and commercial radar, air navigation and guided missile control.

Frequency and time measurement equipment — The principal instruments in this classification are frequency and time standards, digital frequency counters, digital recorders, digital delay generators and tachometers.

Oscillators and vacuum tube voltmeters — This class of equipment is basic for both laboratory and production use. Its applications range from maintenance of telephone systems to development of control systems for industrial and defense needs.



William R. Hewlett and David Packard.

Oscilloscopes — These instruments are also basic mea uring tools in various segments of industry. They compri the field of instrumentation most recently entered by Hew lett-Packard.

There are, of course, several other instruments of miscellaneous nature which are sold both in the U.S. a abroad.

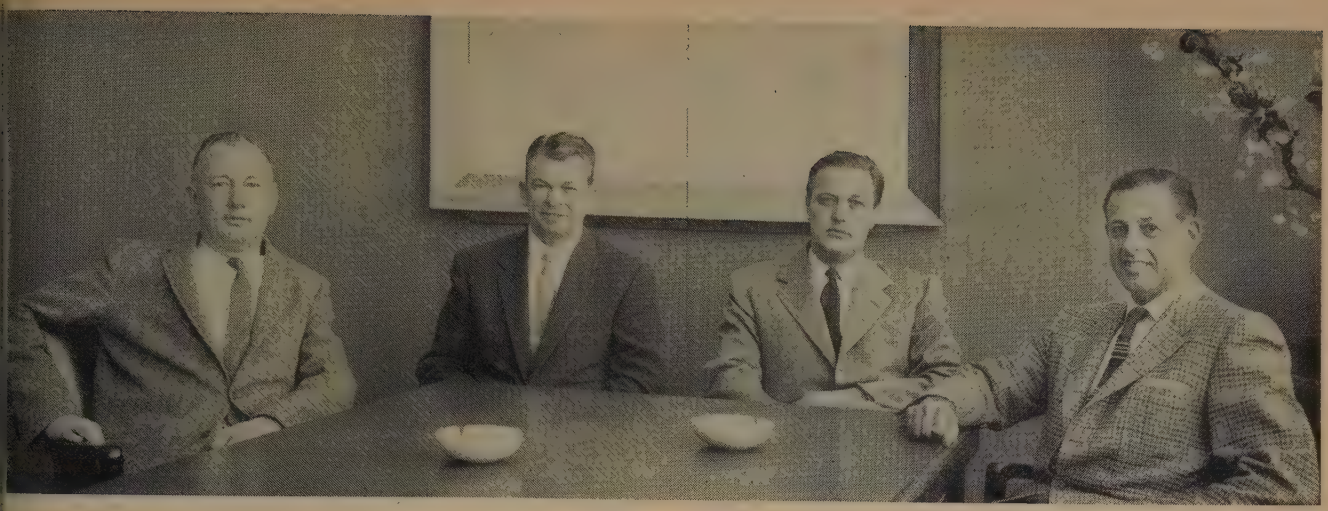
The history of Hewlett-Packard is a story of hard wo and determined purpose. It actually started a few yea prior to 1939 when two young electrical engineers, Dav Packard and William R. Hewlett, were about to gradua from Stanford University. Although they had given co siderable thought to going into business for themselve they were advised by Frederick E. Terman, Stanford world-famous Dean of Electrical Engineering and no Provost, to gain additional experience and knowledge b fore launching their own enterprise.

This they did. Packard went to work for General Ele tric at Schenectady. Hewlett pursued graduate work Stanford, went to Massachusetts Institute of Technolog and then returned to Stanford to do some practical r search. By now, Packard had also returned to the Pa Alto campus on a research fellowship.

On a part-time basis the two informal partners bega building various devices in their first "plant," a sma garage in a quiet residential district of Palo Alto. O of these devices, an audio oscillator, was presented b Hewlett at the 1938 I.R.E. meeting in Portland, Ore. A engineer for Walt Disney Studios was impressed with t instrument and bought nine oscillators for the sound pre entation of "Fantasia."

This "big" order did it. In January, 1939, the compa came formally into existence as a partnership. The ne oscillator, dubbed Model 200A "because the numb sounded impressive," began to pay off immediately. It w followed by a harmonic wave analyzer, then a square wa generator. By 1940 the partners had rented part of small building on Page Mill Road in Palo Alto. At yea end, several instruments had been added to the line, a sma production team had been hired and Hewlett-Packa was on its way.

By 1943, the company was deep into war productio



Company Vice-Presidents Porter, Cavier, Oliver and Eldred.

ıd its 100 employees were turning out $1 million worth instruments annually. The firm had also built the first of s own buildings, a 10,000 square-foot office, laboratory ıd factory. During the war years Hewlett-Packard was varded the Army-Navy "E" for Efficiency honors on four fferent occasions, a distinguished production record.

In 1947 the firm was incorporated and still other prodcts were being developed to meet the needs of an exanding post-war economy. By 1953 sales volume had ached $1 million per month, and *-hp-* had assumed a osition of leadership in the field of electronic measuring istruments. Since then the company has continued to ow — not only in measurable yardsticks such as product ne and total sales, but in stature and reputation among s thousands of world-wide customers.

Dave Packard and Bill Hewlett continue to chart the ourse of their 20-year-old company — Packard as presint and Hewlett as executive vice-president. Both are ell-known throughout the electronics industry, not only r their remarkable achievements in building the Hewlettackard Company but for their active interest and particiation in industry affairs. Their reputation as "doers" exnds into fields outside electronics, as well. Packard, for xample, is chairman of Stanford's Board of Trustees and director of several major corporations. Hewlett also holds veral directorships and is a trustee of Mills College.

Despite their busy schedules and heavy participation in dustry and community projects, Packard and Hewlett eep a firm hand on the tiller. Both are "shirtsleeve" exutives; they spend many hours each week in the comny's laboratories and plants. The doors of their offices e seldom closed — an indication of their easy accessility to employees. As a result, there is a freedom of mmunication at Hewlett-Packard which is unique in a mpany its size and which is a cornerstone of its success.

Another management skill which has contributed greatly the firm's progress is delegation of authority. Packard lieves that it is one thing to give a man the ball and nother thing to let him carry it.

"Here we try to do both," he says. "Generally speaking, e've found this policy results in very few fumbles and great many touchdowns."

Hewlett-Packard's top management team includes four ce-presidents, each responsible for a major function of e company's operation. The V.P.'s are Bernard M. Oliver, research and development; Noel E. Porter, manufacturing; W. Noel Eldred, marketing and W. F. Cavier, finance.

Oliver's research and development group, considered one of the finest in the industry, includes over 150 graduate engineers and scientists who are engaged in the development of new and improved instruments and occasionally in government research projects. The R & D staff includes four principal groups, each concentrating on a given field of instrumentation. One group, under Alan Bagley, is responsible for frequency counters and related instruments. Heading the second division is Norman Schrock, in charge of the oscilloscopes and oscilloscope accessory program. The third division, supervised by Bruce Wholey, is devoted to microwave signal generators, noise meters and noise sources, and waveguide components. John Cage heads the fourth division, which is responsible for audio and video voltmeter projects.

The company has always placed great emphasis on research and development, as evidenced by the heavy and increasing investment in R & D. In 1950, *-hp-* spent $207,000 in development engineering. By 1955 this had increased to $862,000 and in 1960 the company estimates its expenditure will be a whopping $2.6 million.

The effectiveness of this aggressive R & D program is indicated by the productivity of the engineering group. While many instrument manufacturers have only 10 to 15 products in their entire line, it frequently develops this many new instruments in just one year. In 1958, for example, the company introduced to the market 20 new instruments plus related equipment and accessories.

To match the company's growing R & D activity, Hewlett-Packard has been expanding its production facilities. Noel Porter's manufacturing department now operates two Palo Alto plants, one on Page Mill Road and the other on a 40-acre hilltop site adjoining the Stanford University campus. The Stanford plant, as the company calls it, is an ultra-modern facility commanding a magnificent view of the Coast Range mountains and lower San Francisco Bay. It provides the ultimate in working conditions for employees and is designed for maximum production efficiency.

Since quality is such a vital ingredient in its precision instruments, the company maintains extensive facilities for making many of its own parts. Some of the "extra" manufacturing steps it performs to insure top quality products

include the winding of precision resistors on special, company developed equipment; precision electroplating of rare and corrosion-resistant metals; vacuum evaporating metallic films to provide highly stable resistive units for attenuators, and growth of crystals for semi-conductors. Other, more conventional manufacturing procedures include die casting, plastic molding and gear cutting.

In the new Stanford plant, a fabricating and assembly method known as the "product-centered" approach has replaced the conventional "process-centered" manufacturing method. Under the product-centered method, a group of people and equipment are responsible for virtually the complete manufacture of given instruments — from prefabrication to testing. This contrasts with the process-centered approach wherein sub-assembly departments tend to become larger and more complex, and most of those people working on sub-assemblies never see the finished instruments.

"The product-centered method," Porter explains, "gives us better supervision through all phases of production, sharply reduces in-process inventory and creates a greater production team effort. Everybody on the team, of course, has a chance to see the finished product and to take pride in creating it."

Once a Hewlett-Packard instrument has emerged from R & D and is ready for market, it becomes Noel Eldred's baby. Eldred, a Stanford graduate engineer and a veteran of over 20 years in electronic sales, supervises the world-wide activities of over 200 factory-trained engineer salesmen employed by independent sales companies.

On the domestic sales front, the company is represented by 14 organizations who sell to every segment of the electronics industry, to major manufacturing and process industries, and to government and military groups. At present, about 20% of *-hp-* sales are attributed to government agencies, including the military.

Overseas, the company works primarily through independent sales representatives, although it accepts factory-direct orders in 10 foreign countries.

Hewlett-Packard places great emphasis on its sales training program, which includes frequent seminars at the plant to educate field engineers on the application and operation of its new instruments. The company is highly active in industrial shows and technical meetings, and maintains a strong sales promotion and advertising program.

Largely through the efforts of Vice-President Cav
Hewlett-Packard is in an enviable financial posit
Throughout its history, the company has grown with
incurring heavy indebtedness. Its policy has been to p
back profits into the company to foster continued gro
and to maintain its strong competitive position.

As indicated by the company's modest beginnings, H
lett and Packard started their business with a capital
only a few hundred dollars. In 1957 — their 18th y
of operation — the co-founders sold 10% of their sha
of *-hp-* common stock to the public. Today the compa
common shares, sold in the over-the-counter market,
among the more attractive electronic securities and
widely held by institutions and individuals alike.

Among the large family of shareholders are the ma
hundreds of skilled men and women who work for
company. Broad employee ownership of stock is
couraged by management as a means of increasing inc
tive. In 1957, for example, part of the first public offer
of stock was awarded to employees — at no cost to the
selves. In addition to this stock bonus, the company
also adopted a liberal stock option plan whereby e
ployees, after a certain length of service, may advan
geously increase their stake in the company's future.

The stock bonus and stock option plan are only t
facets of Hewlett-Packard's unique and enlightened
proach to employee relations. This approach has attrac
nationwide attention and has been the subject of numer
newspaper and magazine articles. It's the basis for the
heard statement throughout the electronics industry t
Hewlett-Packard is an "exceptionally good place to wo

Hewlett-Packard management emphasizes that its fin
cial incentives are closely tied to recognition of job p
formance. The company's personnel philosophy, accord
to Packard, "stresses the attitude of employees and m
agement in working together for sustained high qua
performance."

Although Hewlett-Packard is now a leader in its fie
the company has no intention of resting on its laurels.
Packard puts it, "No one in this industry can afford
stand still. Besides the incentives provided by keen co
petition, there is always the great demand for new a
better equipment to fill the needs of industry and scienc

As an indication of its restless momentum, 1959 fi
the company embarking on a series of expansion mo

Artist's sketch of Stanford plant. Four of the six buildings will be completed in early 1960.

signed to strengthen its position both at home and road.

On the home front, the firm's rapidly increasing expenditures on research and development have already been entioned. From the standpoint of physical facilities, *-hp-* currently constructing two additional buildings at its w Stanford plant. One building will provide another ,000 square feet of manufacturing space, while the ner will become the company's new administrative headarters. Like their predecessors, these new units will proide the ultimate in working conditions and be a strikgly attractive addition to the California industrial scene.

Also on the domestic front, Hewlett-Packard has been panding its product line and facilities through the quisition of several top-flight companies. Last year it quired 80% of the outstanding stock of the F. L. Moseley ompany of Pasadena, California, manufacturers of X-Y corders and related instruments. Early this year, the Palo to Engineering Company, producers of components and ality transformers, was acquired. This was followed by merger with Dymec, Inc., manufacturer of electronic easuring systems and special measuring equipment.

In August still another expansion move was announced the acquisition of Boonton Radio Corporation, Boonton, J. Founded in 1935, Boonton designs and manufactures gnal generators and other instruments which are comtible with the *-hp-* line. The firm has about 150 emoyees and an annual sales volume of approximately $2.5 illion. Although it is now a wholly-owned subsidiary of ewlett-Packard, Boonton will continue to operate as a parate company.

While these various acquisitions indicate that *-hp-* is ntinuing to expand its domestic operations, it is on the erseas front that the company has been particularly tive.* It has, of course, been exporting its equipment to rious countries for the past several years. With the tablishment of an Export Sales Department in 1954, wever, *-hp-* embarked on a more ambitious overseas arketing program.

As a result of this program, export sales have grown bstantially and now account for over 10% of total *p-* volume. More important from a long-range point of ew, the company has recently taken two major steps hich are calculated to strengthen its foreign marketing sition.

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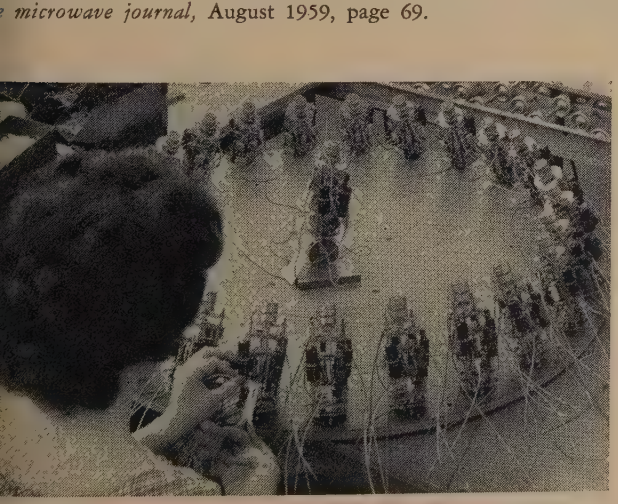
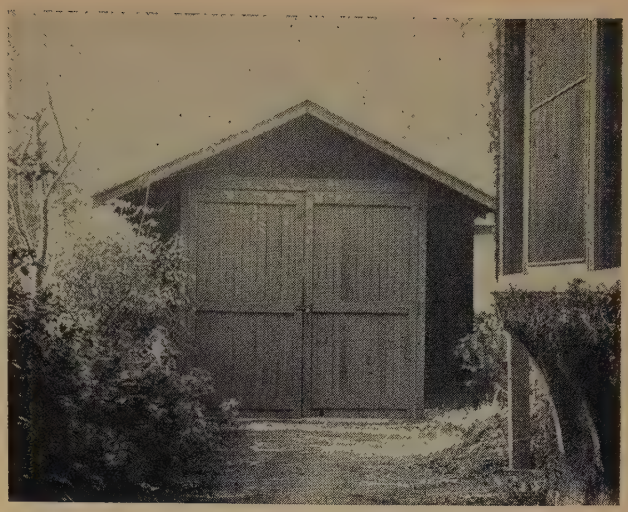
* See "A Look at the Export Market," by Wm. R. Hewlett, *microwave journal,* August 1959, page 69.



"Lazy Susan" technique for assembling intricate parts.



HP's first plant — a garage in Palo Alto.

One was the establishment of Hewlett-Packard S.A., a subsidiary company which is headquartered in Geneva, Switzerland. This firm is coordinating sales activity in Western Europe.

The other expansion step involves the setting up of a manufacturing facility in the Stuttgart area of Western Germany. This plant, representing Hewlett-Packard's first overseas production facility, is expected to be in operation late this year. While its initial output will be relatively small, the company is hopeful that it will eventually become a major manufacturing unit.

In viewing the sum total of these expansion moves, one might gain the impression that perhaps Hewlett-Packard is growing too fast — that it may be overextending itself simply for the sake of growth itself. While this is certainly a pitfall in such fast-moving industries as electronics, an analysis of its growth pattern indicates that the company's expansion moves are preceded by the most careful long-range planning.

The key word behind Hewlett-Packard's growth is *contribution.* Packard believes — and this underlies the company's entire philosophy — that no company should be acquired, that no plant should be built, that no new product should be manufactured unless such action *contributes* directly to the progress of the industry and the company.

"Bill Hewlett and I were able to get started in business because we had something to contribute," Packard points out. "This fact has been the cornerstone of our entire operation. We expect our research people, for example, to contribute new and practical ideas in the field of electronic instrumentation. We expect our manufacturing people to contribute productive skills in turning out inexpensive, top quality instruments. And we expect our sales people to contribute superior and continual service to our many customers. The simple question, 'Will this make a contribution?' is a mighty handy yardstick in measuring the potential value of any new plan or proposal."

Judging from Hewlett-Packard's 20-year record of accomplishments, it appears that the company has more than made its share of significant contributions to scientific and industrial progress. Furthermore, there can be no doubt that as the electronic industry increases in stature and importance, *-hp-* will loom ever larger on America's industrial horizon.

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Dr. Harold I. Ewen, President and Technical Director, says the new offices, research and manufacturing areas, occupying 30,000 square feet, will provide both the added space and specialized facilities necessary to keep pace with the company program of planned expansion.

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Group Directors of Ewen Knight's research and development program functioning under Dr. Ewen, are Hays Penfield, Irwin Richter and John Campbell. Leo F. Mulhern is executive vice-president, and Robert H. Farwell, vice-president.

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HIS MICROWAVE BUSINESS

ORMAN J. ALSTAD was born in 1915 in Decorah, Iowa. He came active in electronics at an early age as an amateur lio operator. He was graduated from Luther College in 1938 th an A.B. Degree. From 1938 to 1942 he was a high school tructor in mathematics and physics in Windom, Minnesota. om 1942 to 1945 he served as an instructor and administrator the Air Force Officers Technical Training School at Yale iversity, also doing graduate work in mathematics.

Mr. Alstad joined Raytheon's Microwave and Power Tube vision in 1945 as a klystron applications engineer. He became nager of the Applications Engineering Department in 1951, ving in this capacity until his recent appointment to manage Product Planning Department.

RELIABILITY AND LONG LIFE IN MICROWAVE TUBES

NORMAN J. ALSTAD, MANAGER, PRODUCT PLANNING DEPARTMENT
MICROWAVE and POWER TUBE DIVISION, RAYTHEON COMPANY

The growth rate of microwave electronics during the t two decades has been influenced to a large extent progress in development and manufacture of micro- ve equipment components. One of the more critical jor components has been the microwave tube. Per- os no other component in microwave equipment re- res as much care in circuit design and proper operat- procedures to realize its full capabilities.

The present stringent requirements for microwave nal sources and amplifiers are familiar to many. The is continually for more reliable operation and longer in more difficult environments, at ever higher peak average power outputs, at higher frequencies, and higher efficiencies with less weight and volume. hough progress in these areas has not been as rapid equipment and military people would wish, much gress has been made by the widening circle of com- ies with active microwave tube development facili-

would especially like to discuss the areas of reliabil- and long life in microwave tubes because in several oects the microwave tube people are not getting a shake on these attributes. Criticisms of these qual- s in microwave tubes are frequently made without sideration of the equipment design and field main- ance shortcomings.

There are undoubtedly many improvements which be made in microwave tube structures and processing mprove operational life and reliability. Every micro- e tube developer known to the author has been hard vork in these areas. As a result, impregnated cath- s, heliarc welding, helium leak detecting, strength ough metal-ceramic construction, and life testing er more adverse conditions than any ever encoun- d in field use are but a few of the recent improve- ts.

When searching for ways to improve reliability and life in microwave tubes, however, it is also well worth while to spend time outside of the immediate tube development areas. In the development or field use of microwave systems for example, even small changes in tube circuitry or operating procedures may have a large effect on microwave tube life and reliability. In our applications engineering experience it has been simple to make necessary circuit or procedural changes in any one system installation to achieve excellent microwave tube life and reliability. To make such changes universal throughout a military command however, is usually a very long and difficult task filled with discouragements.

In examining the development histories and military use of microwave systems, the following specific weaknesses affecting microwave tube life and reliability are noted:

1. Microwave tubes and the equipments in which they are used are frequently developed simultaneously. It has been difficult due to the lack of proper authority, for the military project engineer, the major using commands, the equipment and microwave tube developers to resolve mutual problems without delay, particularly during the last stages of the development program. Equipments therefore go into production and into field use with unresolved engineering problems. (The recent advent of weapons system contracting is placing greater co-ordination authority with the prime contractor. It is still too early to determine the impact of this arrangement on our problem.)

2. Information feedback to the microwave tube manufacturer during the early stages of equipment use in the field has been missing. Factual reports which can be of assistance regarding the performance of microwave tubes in field equipments do not reach the tube manu-

facturer. Thus if he wishes to know the facts, he must place tube experts in the field and gain a working relationship with the military commands using each system. Unless he does this, difficulties which he could help alleviate will not come to his attention until a panic button is pressed. By panic button time, there has usually been a dangerous accumulation of "red time," the overall operation of the system may have been costly and discouraging, and indiscriminate discarding of microwave tubes and other major components may have taken place.

3. In cases where problems of an engineering nature have been detected during the early field use of an equipment, there has been no channel of appeal through which quick action can be achieved. Consequently even simple changes require several years to effect, again resulting in discouraging inefficiencies and costs which could be eliminated by prompt and timely action. The results of the three weaknesses outlined above has been felt by the microwave tube manufacturer in terms of false field claims of unreliability and short life against his products. When he visits the field in such cases, he invariably finds unresolved equipment-component problems and a generally confused picture among military operators and maintenance people due to a lack of understanding of the equipment. A further check usually reveals that this misunderstanding of the equipment is due to the lack of adequate instructional materials and to the rapid turnover of military maintenance personnel.

What can be done to eliminate such problems quickly and obtain increased microwave tube life and reliability? When one considers the situation, it becomes clear that at least one important gear is missing in the liaison machinery of the average military equipment development program. If a small Action Committee with overall system-component-field responsibility and authority were to guide each major development program, the above problems would certainly be reduced.

Before elaborating further on such an Action Committee, I would like to give you one further illustration of the seriousness of the field problem in terms of actual cost in money. For this illustration we will cite the records of just one of the tube reclamation programs being worked on at Raytheon as a cooperative venture with one branch of the military. In this program alone, involving one system and one relatively low power magnetron, 46% of the tubes being removed from the equipment are good tubes meeting all specifications!

The following figures summarize a 6-month period of retest activity in this reclamation program:

	No. of Tubes	*Dollar Value*
Total 2J51A Magnetrons retested	1274	$414,050
2J51A Magnetrons meeting all electrical and mechanical specifications on retest	589	$191,425
Total 2J51A Magnetrons recovered (includes 115 tubes repaired for physical damage and degaussed magnets)	704	$228,800

The 589 tubes which were found to be o.k. on retest would not have been removed from the equipment in the field if the causes for system malfunction had been diagnosed correctly. Failure to make the proper diagnosis has thus resulted in alleged short life and unr liability in the magnetron. Obviously the answer is n a tube reclamation program, but action aimed at t root of the trouble — namely more adequate traini materials which will guide field operators to correc diagnose and pinpoint the real system difficulties.

The need for a responsible Action Committee w authority to act on each major equipment developme problem and field educational need has been appare for some time. Immediate establishment of such grou is certainly feasible, and evidence is piling up all t time, which shows that major gains in microwave co ponent reliability and life would result.

The necessary make-up of an Action Committee quite obvious. Since the customer in all cases refer to is the Military, the chairman of the Action Comm tee would logically be the Military project engine To round out the membership, the headquarters of t major using commands and component develop should be represented.

The major responsibilities of the group would be follows:

1. To study and act on recommendations from t Military project engineer, the equipment, or the co ponent developers in regard to development proble early field problems, etc.

2. To co-ordinate equipment and component spe fications.

3. To take action in the provision of adequate ma tenance and training handbooks, and to see that th aids are available to the field *prior* to the time of equ ment installations.

4. To review and agree on the adequacy of handboo and procedural instructions before they are published.

5. To advise the Weapons Phasing Groups regardi ways and means of improving operation and serviceabil features of electronic equipments.

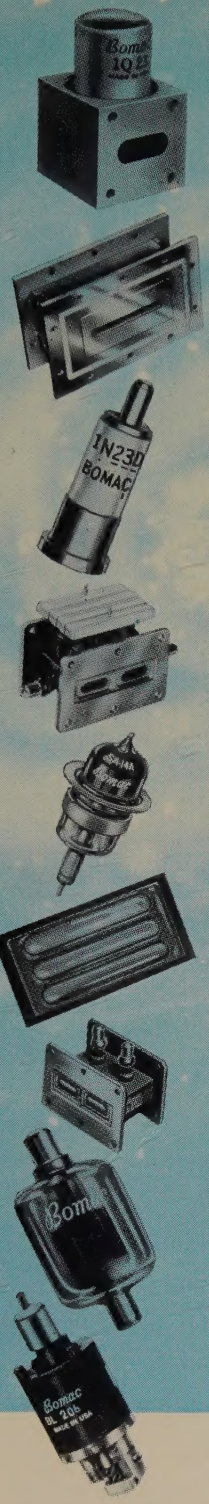
6. To study the minutes of Weapons Phasing Gro meetings to determine what impact their decisions mig have on the work progressing on a major system in equ ment and component development laboratories.

The system Action Committee would thus provide missing link to tie military equipment and compone development efforts together. It would expedite the co mon goal of delivering to the field an electronic syst capable of meeting performance objectives reliably and an early date.

After initial equipment delivery to the field, the co mittee would have authority to take action on remaini design problems, as well as on necessary instructio materials to guide the Military in proper use, main nance, and trouble shooting of the equipment.

The need for the Action Committee becomes m urgent as the complexity of electronic equipments creases. When one considers the difficulties with sim radar equipments of the present, as compared with the doubtedly complex problems which will arise in the phisticated equipments of the future, the need for eff tive early resolution of problems is obvious.

Certainly all equipment and component manufactu would welcome Action Committees and give their wh hearted support to the military in establishing them. I hoped that the Services will open discussions in this a soon and invite industry to take part in organizing s Committees.



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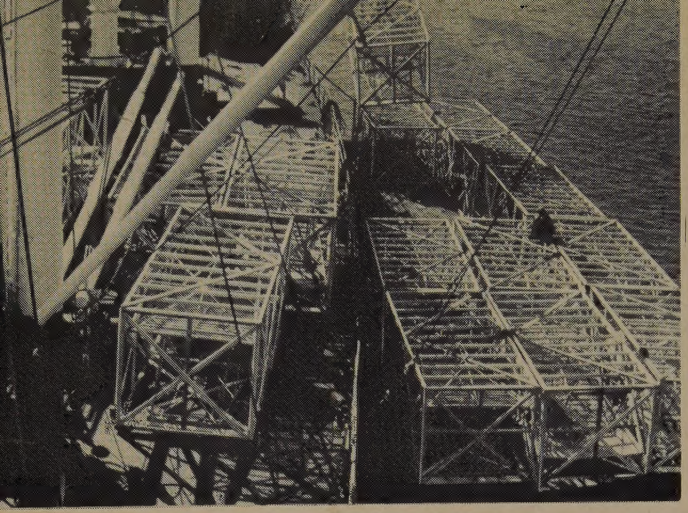

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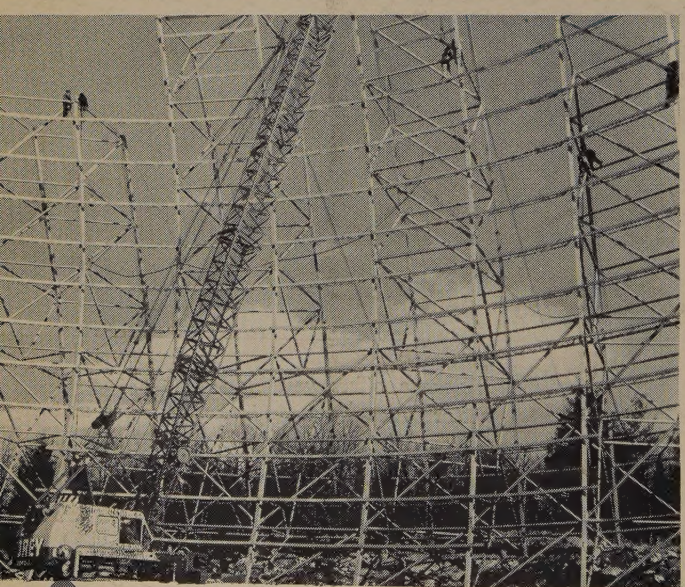

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